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TECHNICAL WORKSHOP

ON

VECTOR CONTROL

(11th August 1989)

JOINTLY ORGANIZED BY

VECTOR CONTROL RESEARCH CENTRE, PONDICHERRY

&

INDIAN PEST CONTROL ASSOCIATION, NEW DELHI

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I MOSQUITO BIOLOGY AND TAXONOMY

There are some 3100 species of mosquitoes belonging to 34 genera. The most important man-biting mosquitoes belong to the genera Anopheles, Culex, Aedes, Mansonia, Haemagogus, Sabethes and Psorophora.

Distribution:

Mosquitoes have a world-wide distribution, they occur throughout the tropical and temperate regions and extend their range northwards into the arctic circle; the only area from which they are absent is Antarctica. They are found at elevations of 5500 mts and in mines at depths of 1250 mts below sea level. Some genera have very restricted distribution and may have been confined to certain areas.

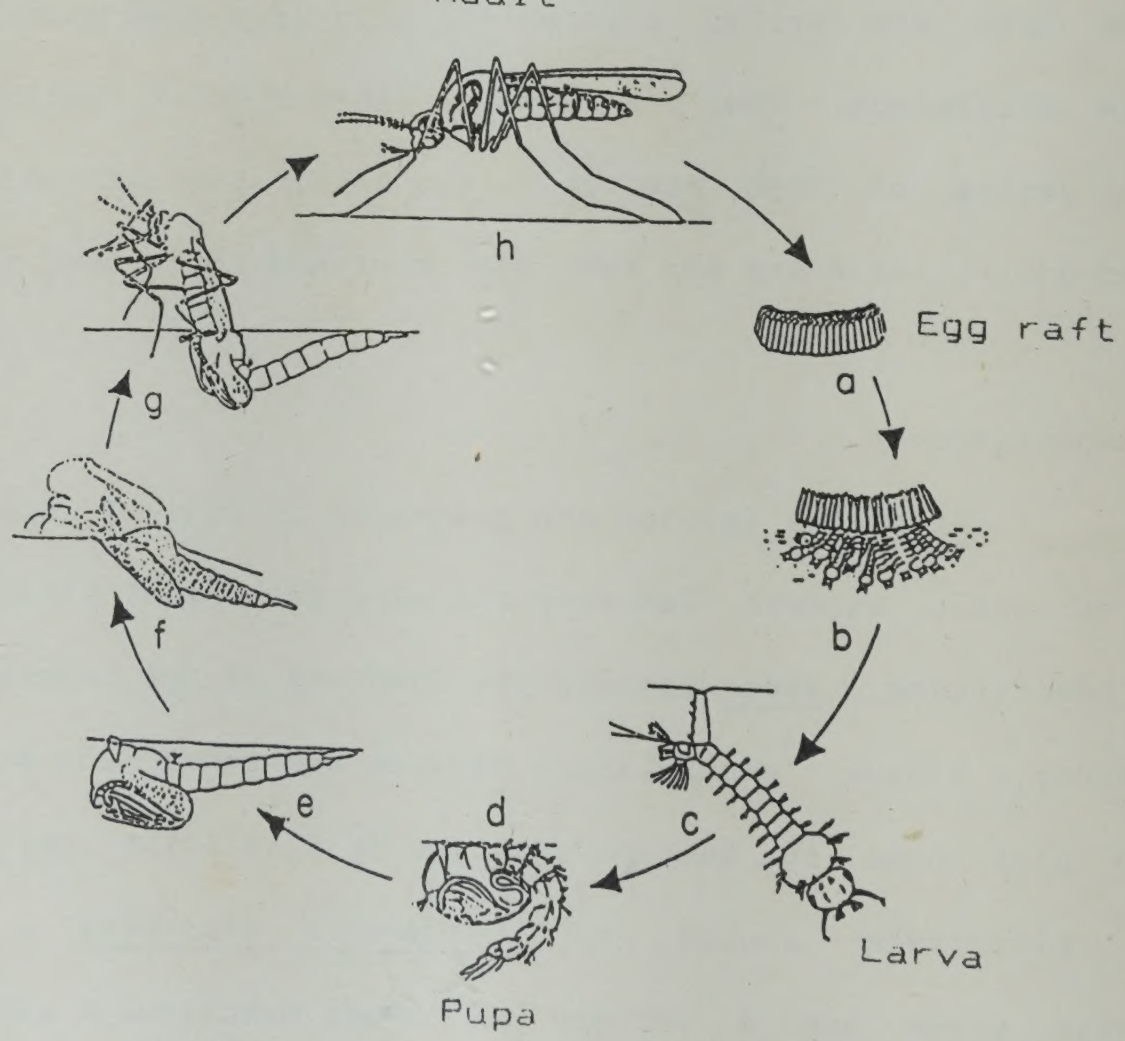
Medical importance:

Anopheles species are primarily of medical importance as vectors of human malaria but they are also vectors of filariasis and certain arboviruses. Aedes species are involved in the transmission of yellow fever, dengue, encephalitis viruses and other many arboviruses and also play role in the transmission of filariasis. Culex species transmit filariasis caused by Wuchereria bancrofti , Japanese encephalitis virus and a variety of other arboviruses and Mansonia

species transmit filariasis caused by Brugia malayi. Haemagogus and sabethes species are vectors (though not in India) of yellow fever and a few other arboviruses. Many other man biting species are a big nuisance to man.

Biology:

The life cycle of a mosquito include 4 stages- egg, larva, pupa and adult (Fig.). The duration of the life cycle depends on some of the abiotic factors, particularly temperature and biotic factors. Most of the species under tropical conditions complete their life cycle in 7-10 days. The life span of the adult also depends on the climatic conditions and it varies widely from species to species.



Life cycle of a mosquito.

Egg: After mating and blood feeding, gravid mosquitoes lay the eggs. Anopheles mosquitoes lay 50-200 small brown or blackish boat-shaped or oval shaped eggs (Fig.). In most Anopheles there is a pair of lateral air filled chambers called the floats on the eggs and these floats are helpful to maintain the eggs on water surface. Culicine mosquitoes lay eggs in the form of a raft (Fig.) which can comprise upto about 300 eggs. But Aedes eggs are laid singly (Fig.) and have the capacity to withstand desiccation. The eggs hatch into first instar larvae. The incubation period i.e. the time from deposition of the eggs to the appearance of fully developed embryo, indicated by the appearance of the first free-swimming larva, depends on the climatological factors and varies from species to species. For ex., at the temperature of about 28 ^{0}c, incubation period of eggs of Cx. quinquefasciatus was 27 hours.

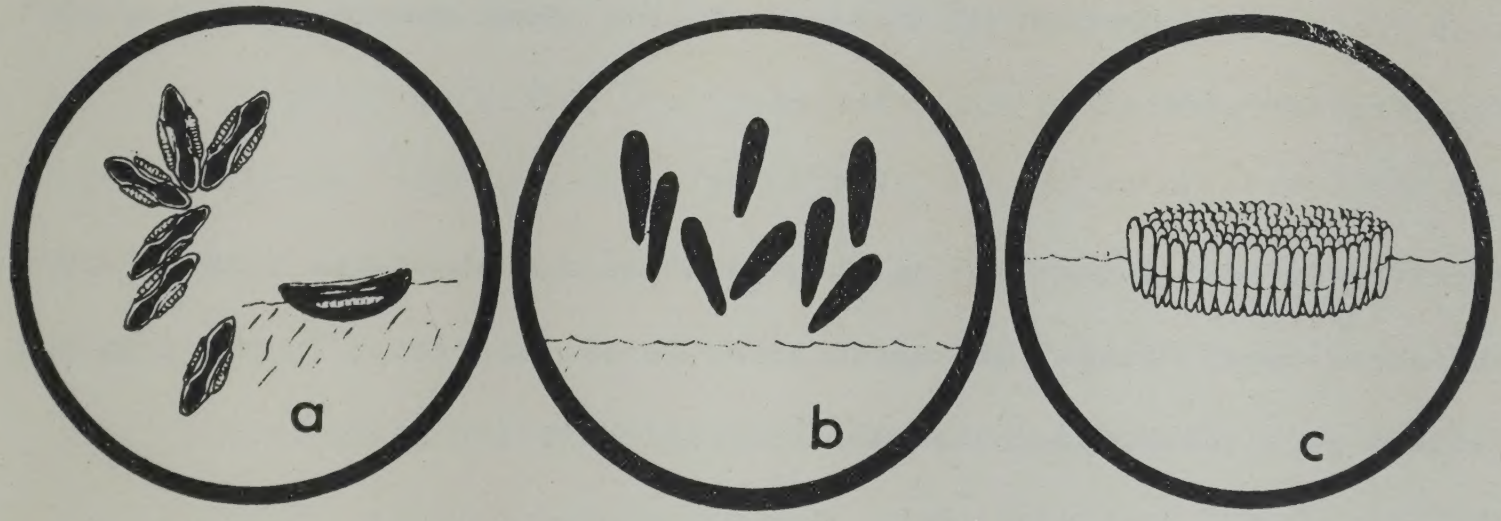


Fig. Mosquito eggs: (a) *Anopheles*, (b) *Aedes* and (c) egg raft of a *Culex* species.

Larva: There are four active larval instars. All mosquito larvae require water for their survival and development and they can not withstand desiccation. Mosquito larvae must come to the water surface to breath but there are a few exceptions. For ex., Mansonia larvae insert their specialized siphon into the roots or stems of aquatic plants from which they draw air. Mosquito larvae feed on yeasts,

bacteria,protozoa and other plant and animal microorganisms found in the water. A few mosquito species are carnivorous and cannibalistic (ex. Toxorhynchites splendens). Under tropical conditions larval development is completed in 6-10 days and in temperate areas it may last several weeks to months. The fourth instar larva develop into pupa.

The breeding habitats of mosquitoes vary from large collections of water such as swamps, rice fields and ponds to small collections of water such as cess pits, drains and puddles. Many species also breed in container habitats like clay pots, water-storage jars, discarded utensils, water filled egg shells, split coconut husks bamboo stumps, leaf axils and pitcher plants etc. The type of the water preferred by species also differ considerably. Few species prefer highly polluted waters, few prefer relatively cleaner water and others some range in between the two extremities. Some species prefer shaded habitats and others sun lit habitats.

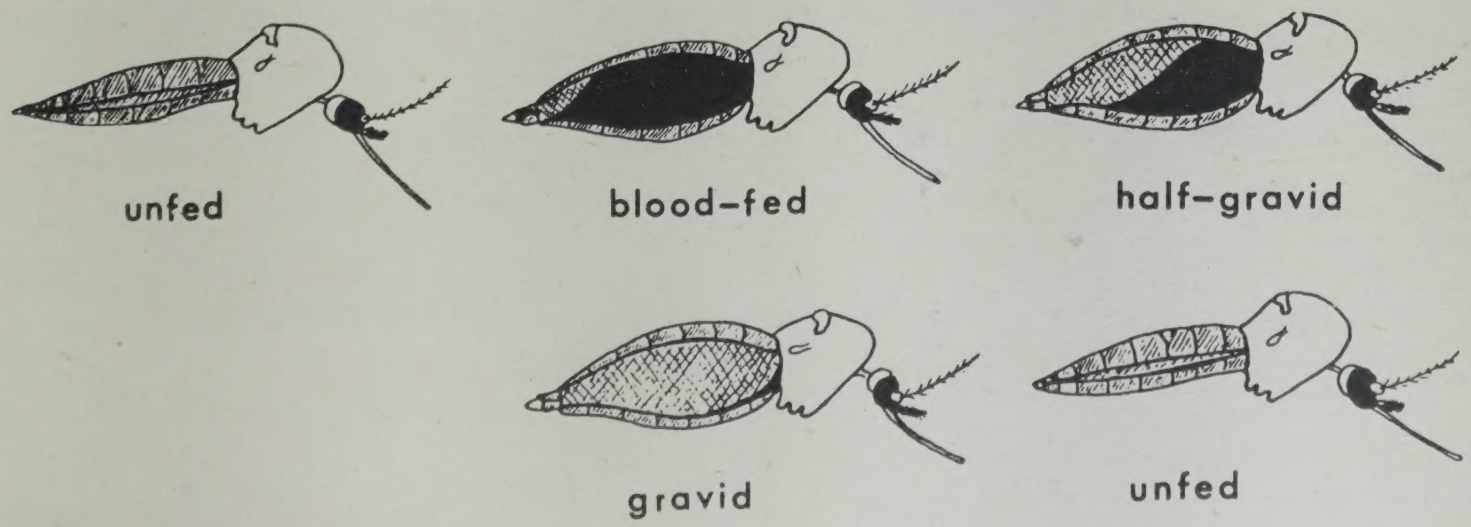
Pupa: Pupa is a non feeding stage and spend most of its time on water surface. Pupal stage of mosquitoes moves actively. In the tropical climate pupal development is completed in about 1-2 days.

Adult: After the emergence of adults from pupa they rest on the water surface or on the edges of the breeding habitat during which their wings unfold and the body wall gets hardened. The duration of this rest phase differ from species to species. Following the complete rotation of the genitalia, males participate in the act of mating. In majority of species males form swarms and females enter these swarms to get inseminated. Light intensity and wind are the important factors that

influence the swarming activity. Swarming and mating usually occurs during dusk.

Following mating a blood meal is necessary for the development of eggs but there are a few species in which development takes place without blood meal. This phenomenon is known as autogeny (ex Cx. molestus). The biting and feeding habits vary from species to species. Some species prefer to bite and feed on man and other species prefer other animals. Species that bite man are called as anthropophilic and that bite other animals (mammals, birds and amphibia) are called as zoophilic. Odour, temperature of and Co 2 emanating from the body are the stimuli that play role in the attraction of the females towards the host. Some species prefer to feed only in the night time and some only during day time and some at any time of the day. The habit of feeding inside the dwellings is known as endophagic and feeding outside is known as exophagic. Same species can be endophagic in one area and exophagic in another area.

After obtaining the blood meal from host, the mosquitoes rest either inside the dwellings or outside, during which period the blood meal gets digested and simultaneously ovary development takes place (Fig.). By the time the blood is fully digested the ovaries are also fully developed (gravid condition) and the eggs are ready for laying. The duration between two successive ovipositions or between emergence and first oviposition is known as gonotrophic cycle.



Blood digestion and ovary development in a mosquito.

The habit of resting outside the dwellings is known as exophilic and inside the dwellings as endophilic.

Each mosquito species has specific combination of various habits like anthropophilism, zoophilism, endophagy, exophagy, endophily and exophily and this combination may change from area to area and from season to season. All these habits assume great importance in the epidemiology, transmission and control of any vector borne disease.

A species must survive a minimum period equivalent to the incubation period of the parasite/pathogen inside the body in order to become a successful vector. The survival of the vector species mainly depends on temperature and moisture.

The gravid mosquitoes are ready for egg laying and they choose appropriate habitat to lay the eggs. The number of the eggs laid by different species vary widely. The eggs undergo further development in the aquatic habitat. The adult, following the egg laying, feeds again on the host and after digesting the blood it lays another batch of eggs and thus the life cycle continues.

Taxonomy:

The Arthropoda constitute the largest phylum of the animal kingdom and, although they include animals differing widely in structure, they agree in certain fundamental characters. In phylum arthropoda, insecta is the largest class. Class insecta is divided into two sub classes - Apterygota and Pterygota. The former sub class includes the wingless insects and the latter all the winged and secondarily wingless insects. The sub class apterygota includes four orders and pterygota includes 25 orders. Of the 25 orders in pterygota 6 viz., Dictyoptera (Cockroaches), Siphunculata (Sucking lice), Hemiptera (Bed bugs and Reduviids), Diptera (Mosquitoes, Sand flies, Black flies, House flies , Tse tse flies, Horse flies and Biting midges), Siphonoptera (Fleas) and Hymenoptera (Bees and Ants) are medically important for man. Again, of these 6 orders Diptera includes the most harmful insects.

Dipterans are two winged insects with suctorial mouth parts large mesothorax and five segmented tarsi. Order Diptera is classified into 67 families of which the insects of following families are involved in the transmission of various diseases. (The detailed classification of order Diptera is given in Annexure 1).

1. Psychodidae	includes sand flies which are involved in the transmission of Leishmaniasis.
2. Culicidae	includes mosquitoes which are involved in the transmission of Malaria, Filariasis, Japanese encephalitis (JE), Dengue and Yellow fever and many other arboviruses.
3. Simuliidae	includes black flies which are involved in the transmission of onchocerciasis.
4. Ceratopogonidae	includes biting midges which are involved in the transmission of Mansonella and Dipetalonema.
5. Tabanidae	include horse flies which are involved in the transmission of loasis.
6. Muscidae	includes house flies which are involved in the transmission of diarrhoea and other bacterial diseases and tse tse flies which are involved in the transmission of sleeping sickness.

Mosquitoes belong to family culicidae. Mosquitoes can be differentiated from other insects by the following characters.

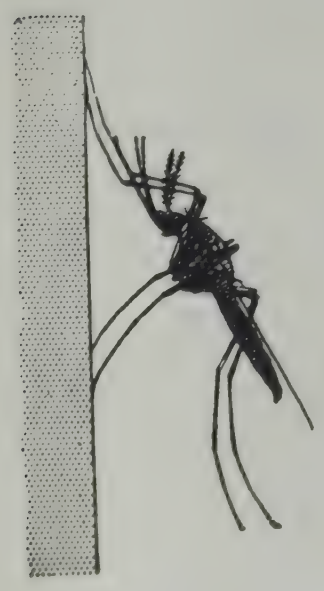
1. They are slender flies, generally with an elongated piercing proboscis.
2. The palpi are stiff and not pendulous.
3. Legs are long.
4. Antennae densely plumose in the males and pilose in the females.

5. Wings fringed with scales along the posterior margin and the second longitudinal vein is forked only once..
6. Larvae and pupae aquatic and very active.

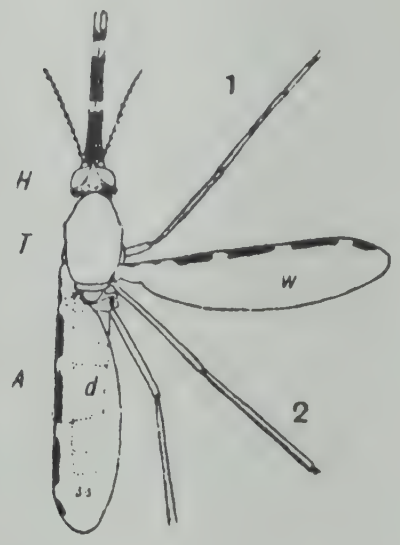
Family culicidae is divided into three sub families:

1. Anophelinae
2. Culicinae
3. Toxorhynchitinae.

The mosquitoes of subfamily anophelinae are generally referred to as anophelines, which include all the malaria vectors and of culicinae as culicines, which include the vectors of filariasis, JE, dengue and yellow fever. Mosquitoes of these 3 sub families differ basically in many characteristics. The anophelines can be differentiated from culicines by the following features.

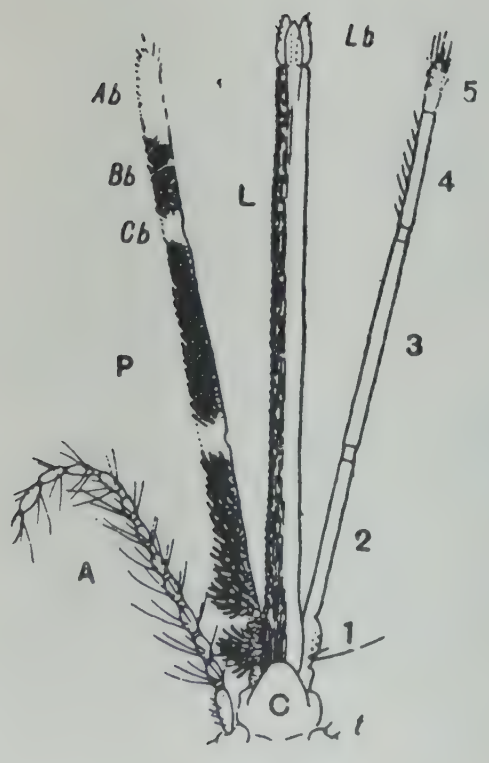
1.Anophelinae	2.Culicinae
1. They rest with the body at an angle to the the surface, that is with proboscis and abdomen in a straight line.	1. They rest parallel to the surface only proboscis may form - slight angle.
	

2. Wings are spotted except in a few species.

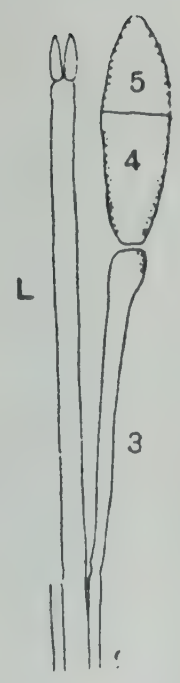


2. Wings are not spotted but uniformly covered with scales.

3. The palpi are as long as proboscis in both males and females. In males they are distinctly swollen and club shaped, ends of palpi sometimes bend outwards away from proboscis.

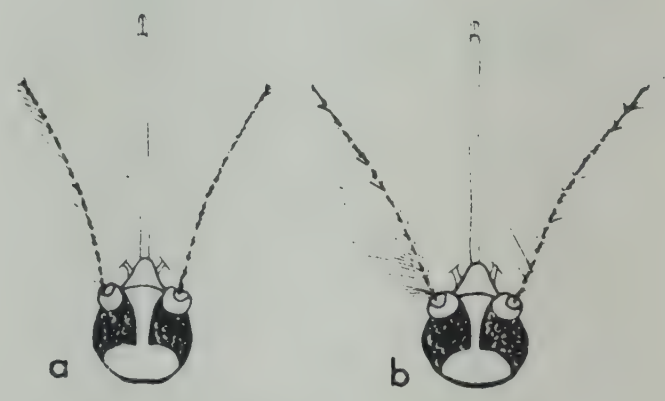


Female



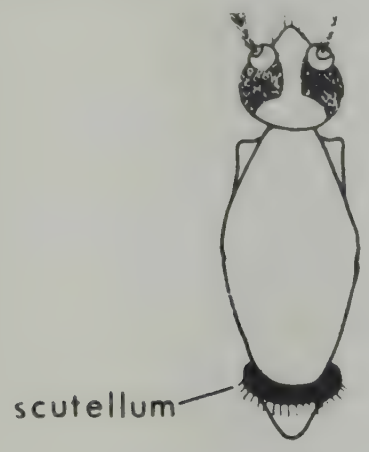
Male

3. Palpi are shorter than proboscis in females. In males palpi are as long as proboscis but are not swollen at their ends.



Females

4. Scutellum is round shaped and has setae along the entire edge.

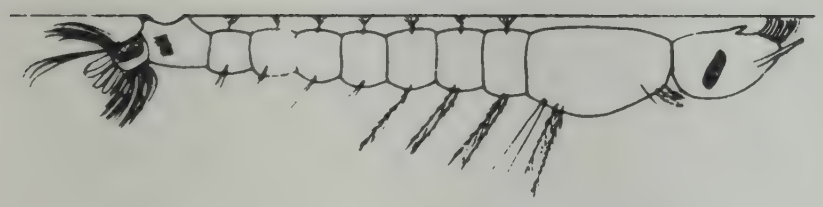


5. Middle lobe of the salivary gland shorter than the lateral lobes.

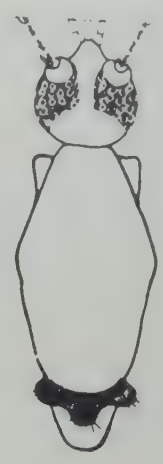
6. Only one spermatheca is present

7. Anopheline larvae float on the surface of water.

8. Siphon tube in larva absent.



5. Scutellum is trilobed and scutellar setae are restricted to these lobes.

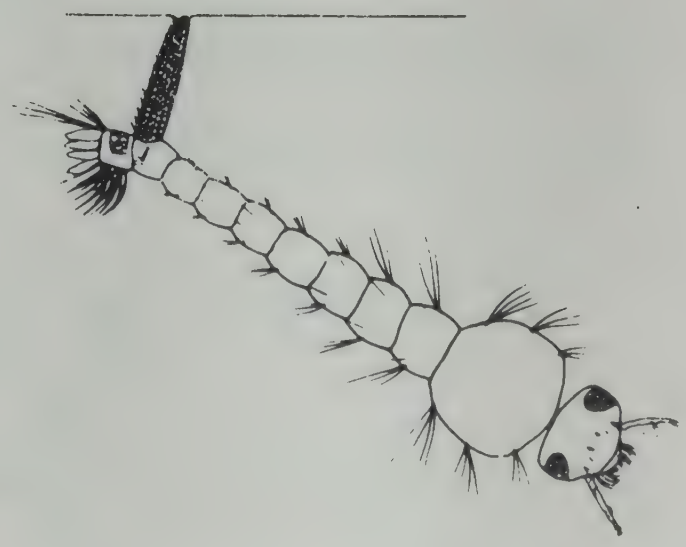


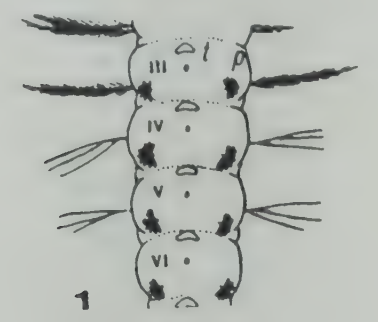
5. Middle lobe of the salivary gland is equal to lateral lobes.

6. Two or three spermatheca present

7. Larvae hang head downwards from the water surface.

8. siphon tube present & at the end of it lies a respiratory opening.



9. Palmate hairs,arranged in pairs are present on many abdominal segments and sometimes on the metathorax in larvae.	9. Palmate hairs absent.
 1	
10.There are 3 genera- Anopheles, Chagasia and Bironella.	10. There are 30 genera.
11.All malaria vectors belong to genus Anopheles, and there are nearly 380 species under this genus.	11. Genera Culex, Aedes & Mansonia are medically important

3. Toxorhynchitinae: This sub family include only one genus- Toxorhynchites. The adults of the genus can easily be identified by their large size and hook shaped proboscis. The larvae are also big in size and are predacious in nature and hence used as a biological control agent against the other species.

Differentiation of various genera: As already noted genera Anopheles, Culex, Aedes and Mansonia are involved in the transmission of various diseases.

Anopheles: Genus anopheles can be differentiated by the characters of its subfamily mentioned above. The genera Bironella and Chagasia are absent in India. Various species are involved in the transmission of not only malaria but also filariasis. Some of the important vector species are listed below. In parentheses is given the name of the disease transmitted by the vector.

An. stephensi (Malaria)

An. culicifacies (Malaria)

An. fluviatilis (Malaria)

An. philippinensis (Malaria)

An. sundaicus (Malaria)

An. balabacensis (Malaria)

An. minimus (Malaria)

An. annularis (Malaria)

An. gambiae (Malaria and bancroftian filariasis)

An. funestus (Malaria and bancroftian filariasis)

An. whartoni (bancroftian filariasis)

An. barbirostris (Brugian filariasis)

An. campestris (Brugian filariasis)

Culex: The mosquitoes of this genus can be differentiated from others by the following characters.

1. Margin of squama (S) fringed (Fig. 1).
2. Vein 6 ending well beyond the level of fork of vein 5 (Fig. 2).
3. Pulvilli (p) present (Fig. 3).
4. Spiracular (sp) and post spiracular bristles (psp) absent (Figs. 4 & 5).

5. Number of species are involved in the transmission of filariasis and JE. The important species are;

Cx. quinquefasciatus (Filariasis).

Cx. tritaeniorhynchus (JE).

Cx. vishnui (JE).

Aedes: The mosquitoes of this genus can be differentiated by the following characters.

1. Margin of squama fringed (Fig. 1).
2. Vein 6 ending well beyond the level of fork of vein 5 (Fig. 2).
3. Ornamentation and scaling very various.
4. Claws of female usually toothed.
5. Pulvilli absent.
6. Number of species are involved in the transmission of dengue, yellow fever and filariasis. The important species are;

Ae. aegypti (Yellow fever & Dengue).

Ae. africanus (Yellow fever).

Ae. simpsoni (Yellow fever).

Ae. polynesiensis gr. (Filariasis).

Ae. niveus (Filariasis).

Mansonia: The mosquitoes of this genus can be differentiated by following characters.

1. Margin of squama fringed (Fig. 1).
2. Vein 6 ending well beyond the level of fork of vein 5 (Fig. 2).

2 3. Tergite 8 of female with a row or patch of short tooth like spines (Fig 6).

4. Yellowish brown, moderate sized and robustly built mosquitoes

5. Larvae get attached themselves to the roots of the water plants like Pistia and Eichhornia.

6. Number of species are involved in the transmission of brugian filariasis. The important species are;

Ma. annulifera.

Ma. uniformis.

Ma. longipalpis.

Further reading:

1. Fauna of British India Diptera Vol. V by Barraud, P. J.

2. Fauna of British India Diptera Vol. IV by Christophers, S. R.

3. Entomology (Medical and Veterinary) by Roy, D. N. and Brown, A. W. A.

4. A catalog of mosquitoes of the world by Knight, K. L. & Stone, A.

5. A guide to medical entomology by Service, M. W.

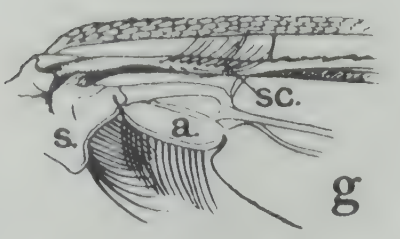


FIG.1 Base of wing from beneath

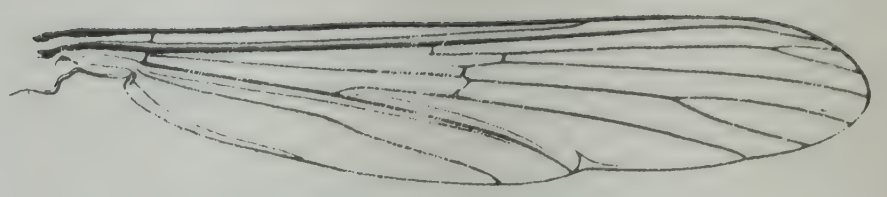


FIG.2 Wing of a culicine mosquito

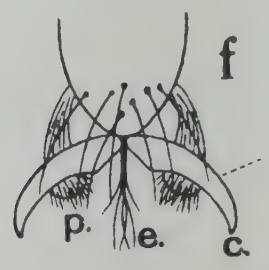


FIG.3 Tip of last tarsal segment of Culex

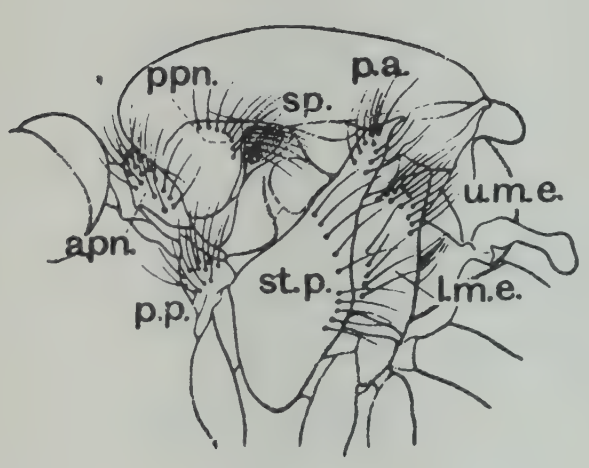


FIG.4 Side view of thorax showing chaetotaxy

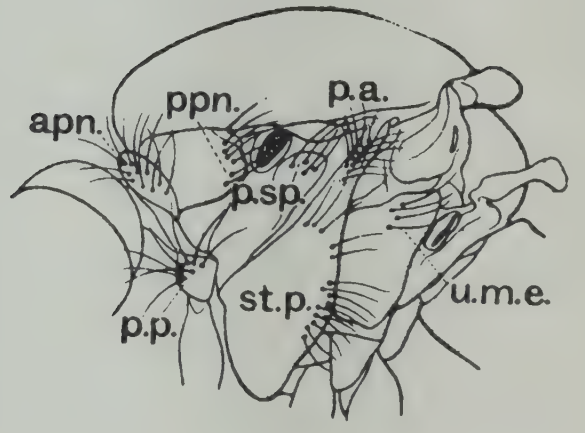


FIG.5

FIG.6 Tergite VIII of female Mansonia

Annexure 1

Order — DIPTERA

Suborder
- 1. Nematocera
- 2. Brachycera
- 3. Cyclorrhapha

Family
- 1. Nematocera — Total 18 families. Important are;
  1. Psychodidae
  2. Simuliidae
  3. Ceratopogonidae
  4. Culicidae
- 2. Brachycera — Total 14 families. Important are ;
  1. Tabanidae
- 3. Cyclorrhapha — Total 35 families. Important are;
  1. Muscidae

Subfamily
- 1. Anophelinae
- 2. Culicinae
- 3. Toxorhynchitinae

Genera
- Anophelinae: Anopheles, Bironella, Chagasia
- Culicinae: Aedomyia, Aedes, Armigeres, Eretmapodites, Haemagogus, Heizmannia, Opifex, Psorophora, Udaya, Zeugnomyia, Culex, Deinocerites, Galindomyia, Culiseta, Ficalbia, Mymomyia, Hedgesia, Coquillettidia, Mansonia, Orthopodomyia, Limatus, Malaya, Maorigoeldia, Phoniomyia, Sabethes, Uranotaenia, Topomyia, Trichoprasopon, Tripteroides, Wyeomyia
- Toxorhynchitinae: Toxorhynchites

II MOSQUITO CONTROL

Choice of control measure will depend on the scale of operation and must be based on a fundamental understanding of the ecology, bionomics and behaviour of the target species and its relation to its host and environment. Control measures can be directed at either the immature stages or the adults, or at both stages simultaneously.

If the control measures are to be undertaken only at individual level, personnel protection measure may play major role. At house hold level only adulticidal measures will be useful and larvicidal measures undertaken in and around house will have limited effect as the mosquitoes emerging from nearby house may invade the house thereby nullifying the effect of larviciding in limited scale.

Whereas if the control measures are to be undertaken in wider area, larvicidal or adulticidal measures may be initiated depending upon the situation. As general guideline larval control measures are preferred in following situations :

1. where adulticidal measures are either cost-prohibitive or nonacceptable to the community ;
2. the breeding is confined to limited area;
3. as preventive measures in areas which are prone to frequent out breaks of vector borne diseases and in situations, where,

for technical or operational reasons house spraying alone or combined with drug administration fails to interrupt disease transmission.

The control measures against adults are preferred in situations, where number of houses to be treated is less than the vast stretch of water-bodies required to be treated for anti-larval measures (mostly rural areas) or where immediate reduction of infected vector population is necessary to contain epidemics.

Control at Household Level:

If the problem is due to Aedes and Armigeres the reduction of mosquito production by preventive measures should be given top priority Since these mosquitoes breed in close proximity to human habitation control could be achieved by source reduction methods. Gardens or backyards should be searched for discarded containers, broken pots, etc which accumulates water and thereby supporting larval breeding. Septic tanks can provide ideal breeding ground for Armigeris ,if not sealed properly. In such situation septic tanks should be properly sealed and vent pipes should be screened with a mosquito netting.

For controlling mosquito breeding in some unused wells the expanded polystyrene beads can be used to prevent egg laying and emergence. Ornamental tanks if any should be stocked with Guppy (Poecellia reticulata) and overhead tanks should be hermetically

ealed. These lavicidal measures in and around house will reduce the rate of reinfestation.

Adulticidal Measures:

Control measures against adults can be done in two ways by using insecticides for indoor residual treatment or space spraying. Generally residual treatment of insecticides is used to control resting insects on various types of surfaces and space spray is used to knock down insects which rests on unsprayable surfaces.

Residual spray: Is defined as spraying of surface with insecticide which may persist for variable periods of time, usually months, so as to cause mortality in resting insects on contact with the treated surface.

The indoor residual treatment is preferred in situations where

(i) the basic resting behaviour of the target vector species is endophilic

(ii) the insecticide deposit should be effective for a longer period against the target species;

(iii) the insecticidal spray should not affect the resting behaviour of the vector species (irritability, excito-repellency) and

(iv) the insecticidal spray should be acceptable to the local community .

Desirable characteristics of a residual insecticide

(i) It should be effective against the vector species and the effect should last for at least three months without repelling or irritating the target species.

(ii) It should produce high mortality with 1 - 1.5 hr of contact exposure to the treated surface.

(iii) It should be less toxic to man and domestic animals.

(iv) It should be stable and should have good mixing and application qualities.

(v) It should be cost-effective.

Application procedures

Hand-operated equipments like hand-compression sprayers and stirrup pumps are widely used for residual spray. However, use of compression spray will reduce the manpower requirement. The frequency of retreatment depends upon the length of residual effectiveness of the insecticide at the dosage used, on the type of surface sprayed, vector bionomics, the climatic conditions.

To prepare the spray solutions for residual applications, the spray suspension can be prepared by using the following formula:

$$X = \frac{250 \times Y \times 100}{C}$$

in which X = weight of the formulated material required

Y = recommended application rate (g (ai)/m^2)

C = percentage concentration of water-dispersible powder

Some of the insecticides available for indoor residual treatment against mosquito vectors are listed below .

Insecticides	Chem. type	Dosage g(ai)/m^2	Estimated effectiveness (months)	Type of activity	Oral LD 50 (mg/kg)
DDT	OC	1-2	6 or more	Contact	113
HCH	OC	0.2-0.5	3 or more	Contact+airborne	100
Malathion	OP	1-2	2 - 3	Contact+airborne	2,100
Pirimiphos methyl	OP	1-2	2 - 3	Contact+airborne	1,415
Dichlorvos	OP	*	1 - 2	Fumigant	56
Chlorphoxim	OP	2	1 - 3	Contact	2,500
Fenitrothion	OP	1-2	3 or more	Contact+airborne	503
Bendiocarb	C	0.4	2 - 3	Contact+airborne	55
Propoxur	C	1-2	2 - 3	Contact+airborne	95
Permethrin	PY	0.5	2 - 3	Contact+airborne	4,000
Deltamethrin	PY	0.05	2 - 3	Contact	135

Space spray:

The adult population can also be controlled by space spraying (atmospheric spraying of insecticide for immediate killing or knock down of flying as well as resting insects in a specified unit area) with insecticides. The prime objectives of space spraying are the achievement of speedy reduction of the adult vector population .

The space sprays should not be recommended as a routine measure to suppress the mosquito density in large scale operations:because,

i) The droplet size of the spray being very small may cause pollution hazards to nontarget organisms including cattle and human.

ii) The cost of the operation and maintenance of the equipment is exorbitant.

iii) The spray generally eliminates the useful predators such as spiders,lizards, Toxorhynchites etc. resulting in resurgence of vector population.

iv) The space spray may lead to misuse of fuel oil used in thermal fogging.

v) Any temporary reduction of population by spray can be compensated by the high reproductive potential of the mosquito vector.

Desirable characteristics of insecticides for space spray

In selecting an insecticide for space spraying, the following factors must be considered:

i) effectiveness against the vector species

ii) availability;

iii) cost;

iv) safety

v) methods available for application and equipment.

Types of space spray

Two forms of space sprays are generally recognized: thermal fogs and ULV cold aerosols. The space spraying can be done indoors or outdoors, depending upon the resting behaviour of the target species. Exterior space treatment can play an useful role to control certain exophilic vector species and interior space treatment can be used to control insects which rest on nonsprayable surfaces. Malathion, pirimiphos-methyl, dichlorvos and pyrethroids such as deltamethrin and bioresmethrin can also be applied as thermal fogs.

Application procedures

Exterior space treatments with cold aerosols are generally made with portable back-pack or vehicle-mounted equipment and interiors with Microsol. Thermal fogging can be performed by vehicle mounted or hand-carried fogging machines.

Some of the common insecticides used for space sprays are listed below:-

Insecticide	Chemical type	Dosage g(ai)/ha	Oral LD_{50} mg/kg (rat)
Fenthion	Organophosphorus	112	330
Chlorpyrifos	"	10-40	135
Dichlorvos	"	56-280	56
Fenitrothion	"	380-580	503
Jodfenphos	"	300-600	2,100
Naled	"	56-280	430
Pirimiphos methyl	"	100	95
Malathion	"	112-693	2,100
Propoxur	Carbamate	53	95
Deltamethrin	Syn.Pyrethroid	0.5-1.0	135
Bioresmethrin	"	5-10	7,000
Resmethrin	"	7-16	2,000
Permethrin	Syn.Pyrethroid	5 - 10	4,000

II.Control at wider scale:

In large scale control programmes first priority should be given to preventive measures particularly for controlling permanent or consistently recurring sources. Whereas when the source is temporary , major emphasis should be towards the immediate elimination of immatures through the application of Biological, Environmental and Chemical methods.

Some of the biological control agents suitable for control mosquito breeding are listed below:

1. Gambusia affinis and other larvivorous fishes	Wells (unpolluted water)
2. Romanomermis iyengari (Nematode)	Grass lands.
3. Lagenidium giganteum (fungus)	Transient pools
4. Toxorhynchites (predator)	Tree-holes
5. Bacillus thuringiensis & B.sphaericus (Controlled release formulations)	Cesspits, Cesspools & disused wells

Environmental methods should aim at eliminating the breeding places that enables the development of mosquito larvae, thereby reducing the carrying capacity of the habitat. This operation can be done either by environmental modification (eliminating the sites permanently) or by environmental manipulation (getting

rid of unstable and small breeding places temporarily).

The improvement of environment like filling, land levelling and drainage should be the first priority in all vector control programmes since they are permanent solution to the control of vectors.

Larviciding has its advantages as well as disadvantages,which are highlighted below:-

i) Mosquitoes developing in an aquatic habitat can be destroyed before they emerge and disperse into the areas inhabited by man

ii) Operations can be programmed and executed within a short period.

iii) There is a large choice of larvicides.

iv) Operational programmes can be easily adapted and the spraymen can be trained in the techniques of larviciding.

v) Since the breeding habitats are mostly outside the premises, acceptance by the community is better than the adulticiding.

vi) The results are of temporary in nature and a continuing programme could be cost-prohibitive in areas where there are large breeding sources.

vii) All insecticides are known to cause health hazards due to prolonged and continuous exposure and therefore the field personnel must be trained in the safety techniques.

Important characteristics for a mosquito larvicide

i) It should be highly toxic to mosquito larvae at lower dosage

ii) It should be rapid in its action and persistent.

iii) Readily obtainable locally at low cost.

iv) It should be safe to handle, transport and apply.

v) Effective in various kinds of water where larvae breed.

vi) It should be non-toxic to non-target organisms.

Application procedures

For applying the larvicides, generally ground equipments such as knapsack sprayers or compression sprayers are used. For the control of *Anopheles spp.*, the larvicides are generally applied at fortnightly intervals and the frequency of application is reduced in standing clear water and at higher dosages.

For controlling *Aedes spp.*, in certain cases, two to three treatments a year, carefully spaced between periods of rainfall would be sufficient.

For controlling *Culex spp.* in slow moving water, the insecticides may be introduced by a drip applicator which can also be used to control breeding in partially closed drains. The rate of flow of insecticide in ml/min in the drip application technique can be calculated by using the following standard formula:

$$Z = \frac{F \times G \times H \times 600}{D \times E \times J}$$

where, Z = rate of flow of insecticide concentrate from drip applicator in ml/min

F = Width of the channel (in metres)

G = Depth of the channel (in cms)

D = Density of the insecticide concentration (mg/ml)

E = Concentration of pesticide concentrate

J = Time taken for water to flow 10 metres in seconds

H = Concentration required in water in mg/l.

Since most of the larvicides in use are available in Emulsifiable Concentrate (EC) formulation, the following formula will be useful in preparing working solutions for spraying with EC and microemulsion formulations.

$$X = (A/B) - 1$$

in which X = parts of water to be added to 1 part of Emulsifiable Concentrate

A = concentration of the EC (%)

B = concentration of the working solution (%)

The low-percentage-concentration granules can be applied through a granular applicator or through a tin with a few holes punched in it. The use of granules is preferred in places where water is scarce.

In the case of application of granular formulation of a larvicide, the following general formula can be used.

$$X \text{ (in gms)} = \frac{V \times Y}{10 \times C}$$

where X = amount of granular formulation required in gms.

V = Volume of the breeding habitat in litres

Y = Concentration of the insecticide to be applied in mg/l

C = Concentration of the granular formulation in %.

With a water dispersible powder formulation, the general formula for preparing the spray suspension has to be used.

$$X = \frac{A \times B \times D}{C}$$

in which X = amount of water-dispersible powder required

A = percentage concentration desired

B = Volume of spray suspension desired

D = 1 if X and B are expressed in kg and litres respectively.

C = percentage concentration of the water-dispersible powder

Choice of insecticides suitable as larvicides

The insecticides recommended for use against the mosquito larvae and the application rates are listed below.

Insecticide	Chemical type	Dosage g(ai)/ha	Formulation	Estimated effectiveness(weeks)	Oral LD_{50} (mg/kg) to rats
Chlorphoxim	OP	100	EC	2-7	2500
Chlorpyrifos	OP	11-16	EC,GR,WDP	3-17	135
Deltamethrin	PY	2.5-10	EC	1-3	135
Diflubenzuron	IGR	20-45	EC	1-2	4640
Fenitrothion	OP	100-1000	EC,GR	1-3	503
Fenthion	OP	22-112	EC,GR	2-11	330
Jodfenphos	OP	50-100	EC,GR	7-16	2100
Malathion	OP	224-1000	EC,GR	1-2	2100
Methoprene	IGR	100-1000	SRS	4-8	34600
Paris green	*	840-1000	Dust, Soln in oil	2	22
Permethrin	PY	5-10	EC	5-10	4000
Phoxim	OP	100	EC	1-6	1000
Pirimiphos-methyl	OP	50-500	EC	1-11	1415
Temephos	OP	56-112	EC,GR	2-4	8600

OP = Organophosphorus; PY =Synthetic pyrethroids;IGR = Insect Growth Regulators; * = Copper-Arsenic complex;EC = Emulsion concentrate; GR = Granular formulation;WDP = Wettable powder; SRS = Slow Release Suspension; Soln = Solution.

However, rate of application may vary from habitat to habitat and usually have to be increased if the water is highly polluted or contains substantial amounts of vegetation.

Controlled release formulations:

In Urban Mosquito Control programmes, the use of larvicides and IGRs has been found to be effective for one week at the concentration of 1 mg/l. The larvicidal application needs more manpower and weekly spraying. In order to reduce the frequency of application, controlled release formulations using Cork powder,- Jiggieth (binding agent) and plaster of paris in a ratio of 1:2:4 impregnated with fenthion have been found to be effective for 1 month. These formulations are easy to apply and transport. This pellet can be applied at the rate of 1 pellet containing 4g(ai) per 100 lit of water.

Monomolecular Surface Films:

The monomolecular surface film producing compounds reduce surface tension and prevent the larvae and pupae from coming up to breathe and cause adults to drown as they emerge. The mode of action is purely physical which will not give rise to resistance. These are non-toxic and biodegradable which can be used in relatively low dosages of 0.2 to 1 ml/m^2.

There are three groups of products that are promising:

1. Isostearyl alcohol, or ISA 20E, with trade name "Arosurf"
2. Sorbitan monooleate or SMO
3. Oleyl ether + cetyl stearyl ether (monoxy FCM)

PRECAUTIONS

Care must always be taken not to exceed the recommended dosage when the larvicides are applied to water which might be used by humans or domestic animals.

Care must be taken to protect spraymen, the public and domestic animals from unnecessary or prolonged exposure or accidental ingestion of insecticides.

Spraymen should be well protected to avoid exposing their skin to insecticide concentrates and should avoid inhaling the insecticide droplets. The public should be well informed about the type and period of spray to take safety precautions.

REDUCTION OF MAN - VECTOR CONTACT

Repellents: Repellents such as DEET and DEPA applied to skin and clothing give protection against man-biting pests for 4 - 8 hours. They are useful during visits to highly pest infested areas.

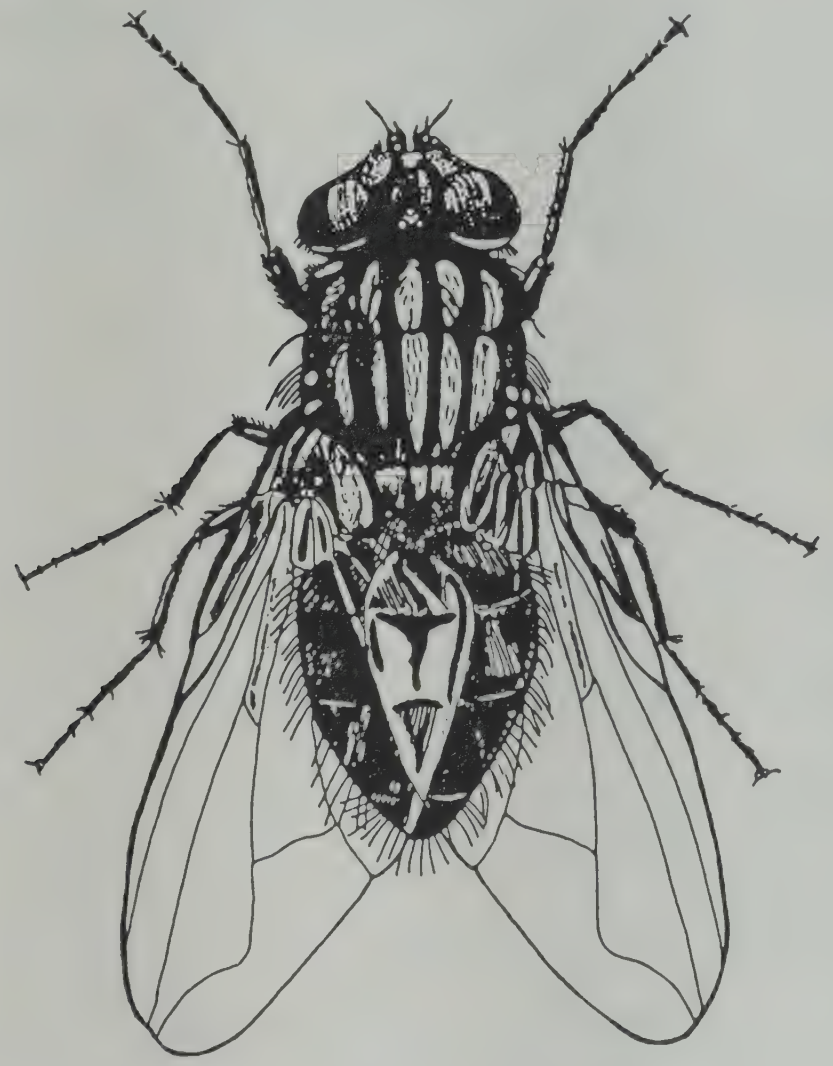
Insecticide impregnated nets and curtains: Mosquito nets and curtains impregnated with permethrin (0.5 g (ai)/m^2) and deltamethrin (0.025 g (ai) / m^2), the synthetic pyrethroids can reduce both man-vector contact and vector density in disease endemic areas.

Mosquito coils, mats and canisters: The formulations such as mosquito coils and mats can be effectively used by the communities. The active ingredicnt is generally a synthetic pyrethroid (d-allethrin) and the vapours released act simultaneously through their knock-down effect, repellent effect and inhibition of biting. The use of some of these formulations is limited owing to the availability of electric current and cost.

* * * * * *

III BIOLOGY AND CONTROL OF HOUSEFLY

The common housefly Musca domestica Linnaeus is synanthropic, i.e. occurs in all parts of the world where there are human settlements. It breeds profusely in animal manure and garbage and move to the human residences and creating nuisance. The role of houseflies as a carrier of disease causing pathogens was suspected long back, but only in recent times its public health importance is well understood.



Musca domestica domestica L. female

Public health importance of Housefly:

After the discovery of microscope many disease germs were isolated from flies. The transmission of pathogens is mechanical and the fly acts as a physical carrier but none of the

pathogens undergoes obligatory cyclical development in its body. The important disease that may be transmitted by the flies are summarised below:

PUBLIC HEALTH IMPORTANCE OF MUSCA DOMESTICA:

PATHOGEN	DISEASES
1. VIRUS:	Poliomyelitis, Trachoma, Cocksakie &ECHO virus and Infectious hepatitis.
2. RICKETTISIA	
Coxiella burnetti	Q fever.
3. BACTERIA	
a) Salmonella	Typhoid, Paratyphoid, Enteritis and food poisoning etc.,
b) Shigella	Bacillary dysentry and other diarrhoel diseases.
c) Cholera vibrae	cholera.
d) Campylobactor fetus jejuni	campylobacteriosis
4. PROTOZOA:	
a) Entamoeba	Amoebic dysentry
b) Giardia	Giardiasis
5. HELMINTHS:	
a) Roundworm (Ascaris)	Worm infestations
b) Whipworm (Trichiuris)	
c) Pinworms (Enterobius)	
d) Hookworm (Ancylostoma)	
e) Strongyloides	
f) Tapworm (Taenia)	
OTHER DISEASES	
1. EYE DISEASES	Endemic conjunctivitis (Bacillary) and Trachoma (Viral)
2. MYIASIS	Urogenital myiasis and Traumatic myiasis
3. INFECTION TO SKIN AND WOUNDS	Cutaneous diphteria, Mycoses, Yaws & Leprosy

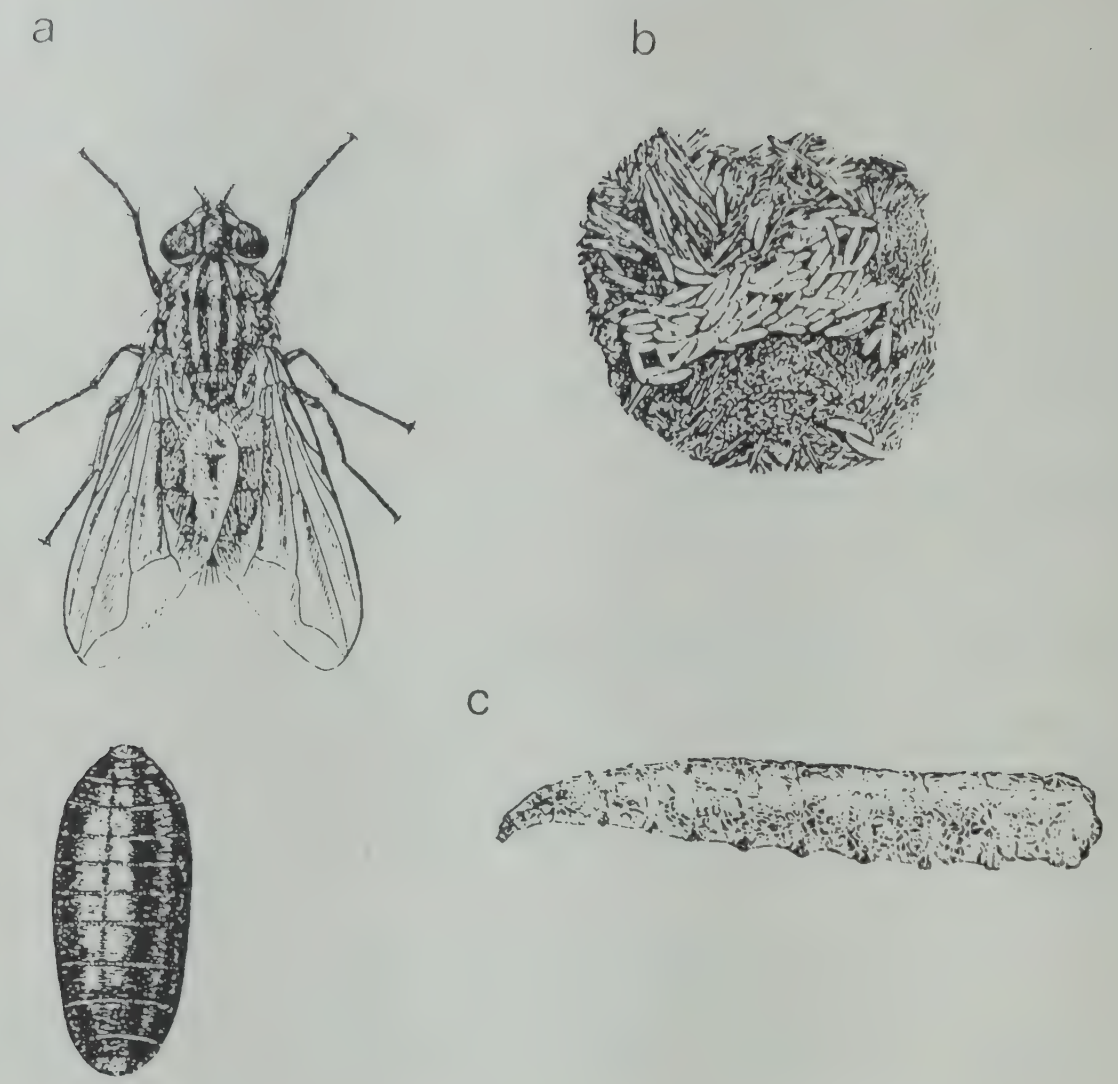
Taxonomy:

The housefly belongs to the class insecta in the order of Diptera along with the majority of two winged insects and under the sub order Cyclorrapha. It is included in the family Muscidae along with other synanthropic flies. Musca species are medium sized flies with non metallic black and grey striped thorax and a sharp angle in the fourth longitudinal vein of the wing. Earlier taxonomists distinguished four different sub species namely Musca domestica domestica, M. d. nebulo, M. d. vicina and M. d. curviforceps. But according to recent investigations of Succa (1967)and Paterson (1974) that all Musca domestica outside Africa should be regarded as one sub species namely Musca domestica domestica.

Life history and biology:

a) Eggs: The eggs of houseflies are 1-1.2 mm long, opal white to cream coloured. Each female can lay about 120 eggs per oviposition every other day under favorable conditions.

b) Larvae: The egg hatches into larva after 6-8 hours at 35 °C and there are three larval instars. The first instar larva is 1 to 3 mm, the second instar 3 to 5 mm and third instar 5 to 12 mm in length. The larvae has a cylindrical body and a conical anterior tapering and a rounder posterior, with no appendages. The food of larvae comprising of bacteria, yeasts and their decomposition products. The larvae try to escape light by burrowing into the manure. The third instar larva is called prepupa they stop feeding and ready to pupate and seek drier substrata. The period of development from egg to pupae depends on nutrition, moisture and temperature with a minimum of 3 to 3.5 days under 35 °C.



The life cycle of the housefly
a. Female b. Egg batch from one oviposition of one female. c. Fully grown third instar larva, d. Puparium

c) Pupae: The pupae is barrel shaped and it is brown or dark brown in colour. The duration pupal stage depends on humidity and temperature with minimum of 3 to 4 days under 35 °C and 90% R.H. The adult fly emerges from the puparium by breaking open the fore end of the puparia. The newly emerged fly is wingless and with in a few hours it stretches wings and develops colour.

Mating and oviposition:

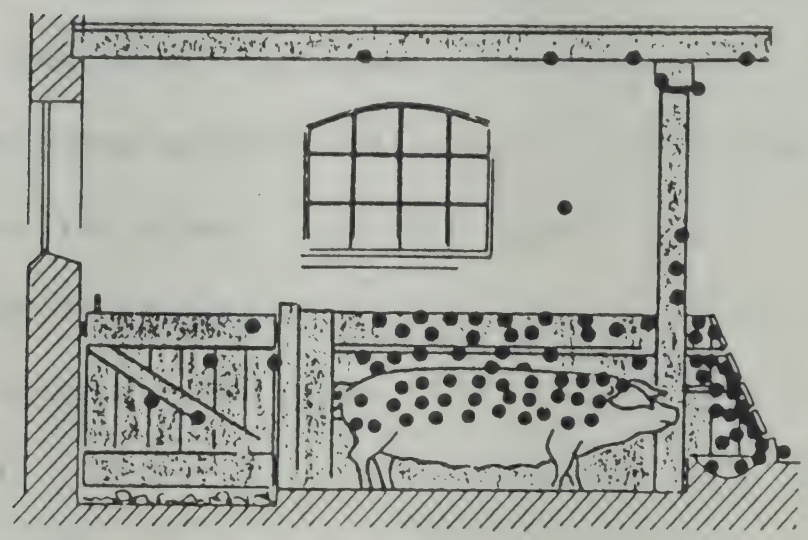
Males are able to copulate day after emergence with in a minimum of 18 hours and females are at an age of 30 hours. Housefly females are monogamous, it has only one effective mating and the sperm is stored in the spermathecae of females and can fertilize the eggs for a period of 3 weeks or more. The preoviposition period is 1.8 days at 35 ^{o}C and the gravid females are attracted towards the breeding media by its smell. The average numbers of eggs laid by a female per oviposition is 120. In laboratory colonies 9 to 10 batches of eggs are laid. The reproductive potential of housefly is so high that a pair of houseflies may be progenitors of 191×10^{18} flies in four months time if all were to live. The number of generations in a year under tropical conditions are around 30 and 10 or less in temperate conditions.

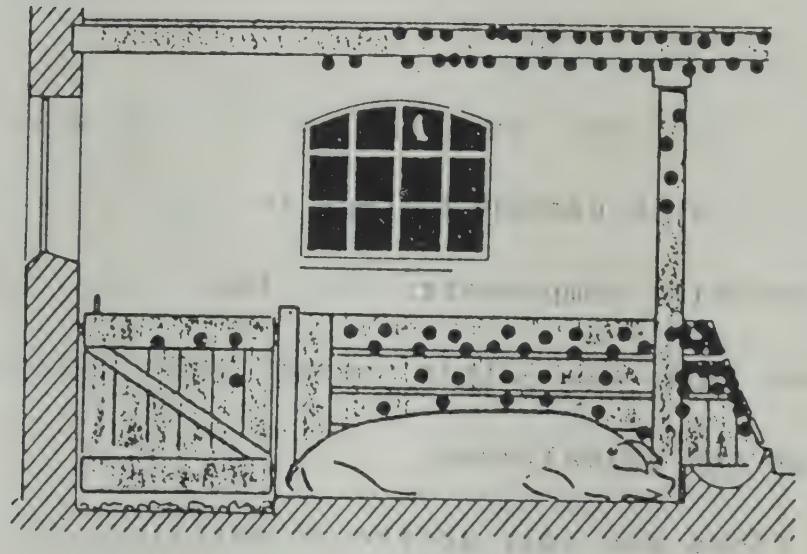
Biology and behavior of adults:

Housefly males and females can survive well on water and sugar or assimilable carbohydrates, in addition females require protein or protein components for the development of eggs. Housefly feed on all kinds human food, garbage, excreta including sweat and animal dung.

Adult flies are only active in day light or in artificial light, whereas in darkness they rest or crawl slowly. Houseflies spend a considerable amount of time outdoors during warm seasons but in cool seasons they prefer indoors. Houseflies leave their places of day time activity and move to special resting sites close by during dusk. In warm nights they prefer to be outdoors

on vegetation and other objects. during cools nights with temperature below 20 C they remain indoor resting on hanging objects like wires, cords and other narrow objects.





Distribution of houseflies in a Danish piggery by day (top) and by night. Each dot represents 1% of the flies and the diagram shows the average counts over several summer days. Such counts have been the basis of strategic fly control.

Breeding sources:

a) Dung: Dung is the original source of housefly breeding. M.domestica breeds in accumilations of dung of most domestic animals and birds provided it has the right moisture and texture. Pig dung is the most preferred and productive type of dung. Dung is suitable only in the first few days to a week after deposited.

MANURE HEAP

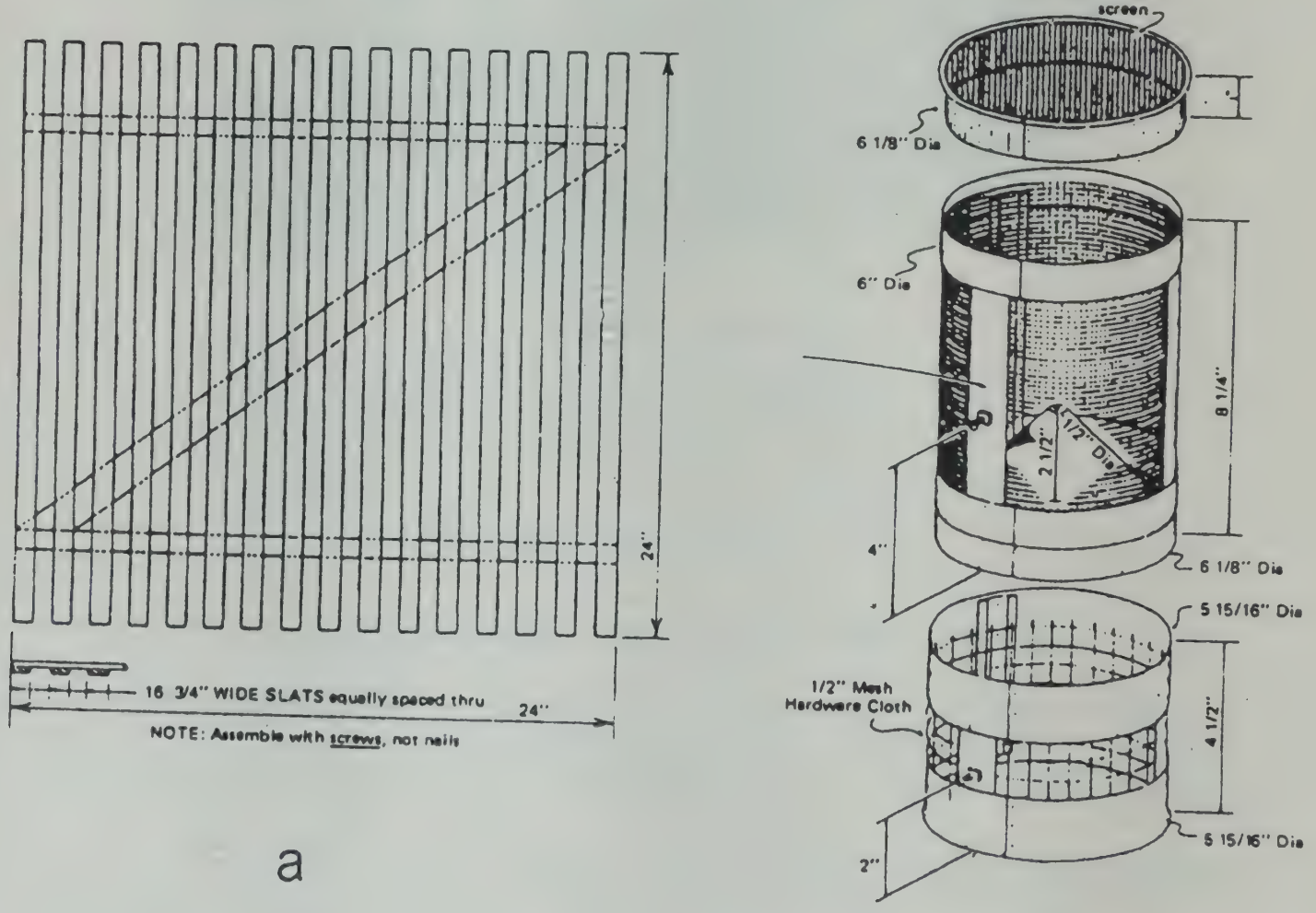
b) Garbage and waste from food processing: In urban areas it is the predominant source for houseflies and other synanthropic flies. Fly breeding may occur in soil mixed with garbage or contaminated with seepage. The wastes from various food processing industries serves ideal source for housefly breeding.

c) Organic manure other than dung: Agricultural fields which are heavily manured with organic manures such as excrement garbage, fishmeal, oil seed cakes, prawn dust etc. facilitate housefly breeding.

d) Sewage: Under suitable conditions houseflies may breed in sewage sludge and solid organic waste in open drains, cesspools, seepage pits etc. or in sewagebeds.

Fly survey methods:

a) Fly grill: The grill is made up of 16 to 24 wooden slats and also called Scudder's grill. It is widely use for estimating relative fly density. The grill is placed near natural fly concentrations and total number of flies landing on the grill during a period of 30 seconds are counted.



Devices for fly survey. a. Fly grill; b. Bait trap

b) Baited trap: It has a cylindrical screen wire cage with an inverted cone entrance. Bait used in the trap is a granulate containing 0.025% muscamone and 1% methomyl. Baited trap is useful for fly surveys especially for qualitative sampling of the fly fauna for identifications.

c) Sticky tape: Sticky tape or strips are widely used for assessing fly densities particularly indoors but also to some extend outdoors.

d) Other survey methods:

i) Counts of flies landing on baits.

ii) Counts or estimates of flies on available surfaces.

iii) Catching of flies by sweepnet.

iv) Catching of flies by using a movable suction device.

v) Counting fly specks.

vi) Fly cone.

Control

To obtain a long term fly control in urban areas, villages and other settlements including farms, improved environmental sanitation is absolutely fundamental, and chemical fly control can only be a supplementary to sanitary measures. The basic principles fly control in tropical regions are

a) Reduction of fly breeding by eliminating sources suitable for fly breeding or by prevention of flies from egg laying in wastes and excreta and by killing larvae in infested materials.

b) Elimination of sources of attraction and to reduce immigration of flies from other areas.

c) To exclude flies from contact with matter containing pathogenic germs and

d) To protect food utensils and man from contact with flies.

Fly control in houses and residential areas :

Community fly control can be achieved by organizing rational waste collection and waste disposal measures. It is absolutely necessary to make the people to understand the importance of keeping their premises and surroundings clean by correct disposal and storage of wastes and excrement and assisting sanitary measures organized by the community. This can be made possible by intense health education and enactment of rigorous public health laws.

Some of the community fly control activities carried out by the various fly control programmes in different countries are

a) Fly proof latrines and water seals (W. Malaysia).

b) Garbage cans (U.S.A.).

c) Refuse container (Israel).

d) Garbage disposal by sanitary land fill (U.S.A.).

e) Using incinerator to burn the garbage (Syria).

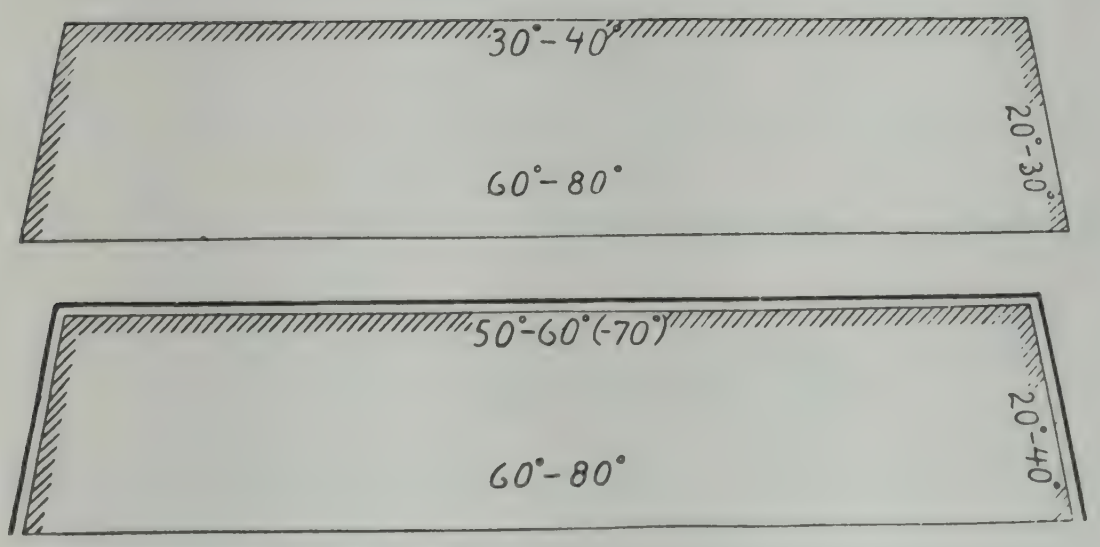
f) Screen door to prevent fly assessibility (U.S.A).

g) Bead curtain at the entrance of houses to prevent fly entry (France).

h) Light traps with electrocutor (Lebanon and Denmark).

i) Fly swatter to kill the adult flies (China).

Dung heap covered with heavy plastic sheet



Temperatures in a dung heap before (top) and after covering with tarpaulin.

Fly control in confined animal management:

In modern live stock production systems, since a large numbers are animals are confined, consequently the accumulations of large amount of manure form the ideal breeding medium for fly production. The movement of flies from breeding places to near by residences creates annoyance. Flies can be controlled at acceptable low levels by proper management practices.

a) Covering of the surface of the manure heap: The manure heap can be covered with a thick layer of straw or with a plastic sheet prevents the accessiblity of fly for oviposition, it gives a neat look to the place and also increases the temperature of fermentation heat above 45 ^{o}C and thus the fly immatures already present are killed by the heat.

b) Drying of the manure: The degree of dryness and piling or "cone formation" by the accumulated manure determines the amount of fly breeding. In dry state of the the manure reduces the suitability for fly oviposition and larval development. The dryness of the manure provides ideal condition for the population of predators and parasitoids attacking fly eggs and larvae and provides a favourable habitat for pupal parasitoids.

Biological control:

A rich variety of predators ad parasitoids attack the different stages the housefly. The eggs and immatures are attacked by the co-existing invertebrate fauna present in the breeding habitat and the adult flies are predated by both other predators. The role of different predators and parasitoids in the regulation of housefly population are given in the table.

NATURAL ENEMIES OF MUSCA DOMESTICA.

NATURAL ENEMIES	FLY STAGE ATTACKED
I. PATHOGENS:	
1. *Bacillus thuringensis* sero type 1	Larvae
2. *Entomophthora muscae*	Adults
II. PREDATORS:	
1. Macrochelid mites	
a) *Macrocheles muscadomesticae*	Eggs and small larvae
b) *Fuscoropoda vegetans*	Eggs and small larvae
2. Larvae of black garbage flies	
a) *Ophyra leucostoma*	Larvae
b) *Ophyra aenescens*	Larvae
3. Larvae of false stable fly	
a) *Muscina stabulans*	Larvae
4. Adults of robber flies	Adults
5. Adults of dung flies	
a) *Scatophaga stercoraria*	Adults
6. Ants	Eggs, Larvae, Pupae and newly emerged Adults
7. Earwigs	
a) *Labia minor*	Eggs and small Larvae
8. Beetles and their larvae	
a) Staphylinids (Rove beetles)	Larvae, Pupae and Adults
b) Histerids (living in dung)	Larvae
c) Hydrophilids (living in dung)	Larvae
9. Other predators	All predating adult flies
a) Spiders(Trochosa)	
b) Mantids	
c) Predatory Wasps	
d) Amphibians (Toad)	
e) Reptiles (Geckoes & Lizards)	
f) Birds (including Chickens)	
III. PARASITOIDS:	
1. *Pteromalid wasps*	
a) *Splangia sp.*	Pupae
b) *Pachycrepoideus sp.*	Pupae
c) *Nasonia sp.*	Pupae
d) *Tachinaephagus sp.*	Larvae
2. *Chalcid wasp*	
a) *Dirhinus sp.*	Pupae
3. *Staphilinid beetle*	
a) *Aleochara sp.*	Pupae

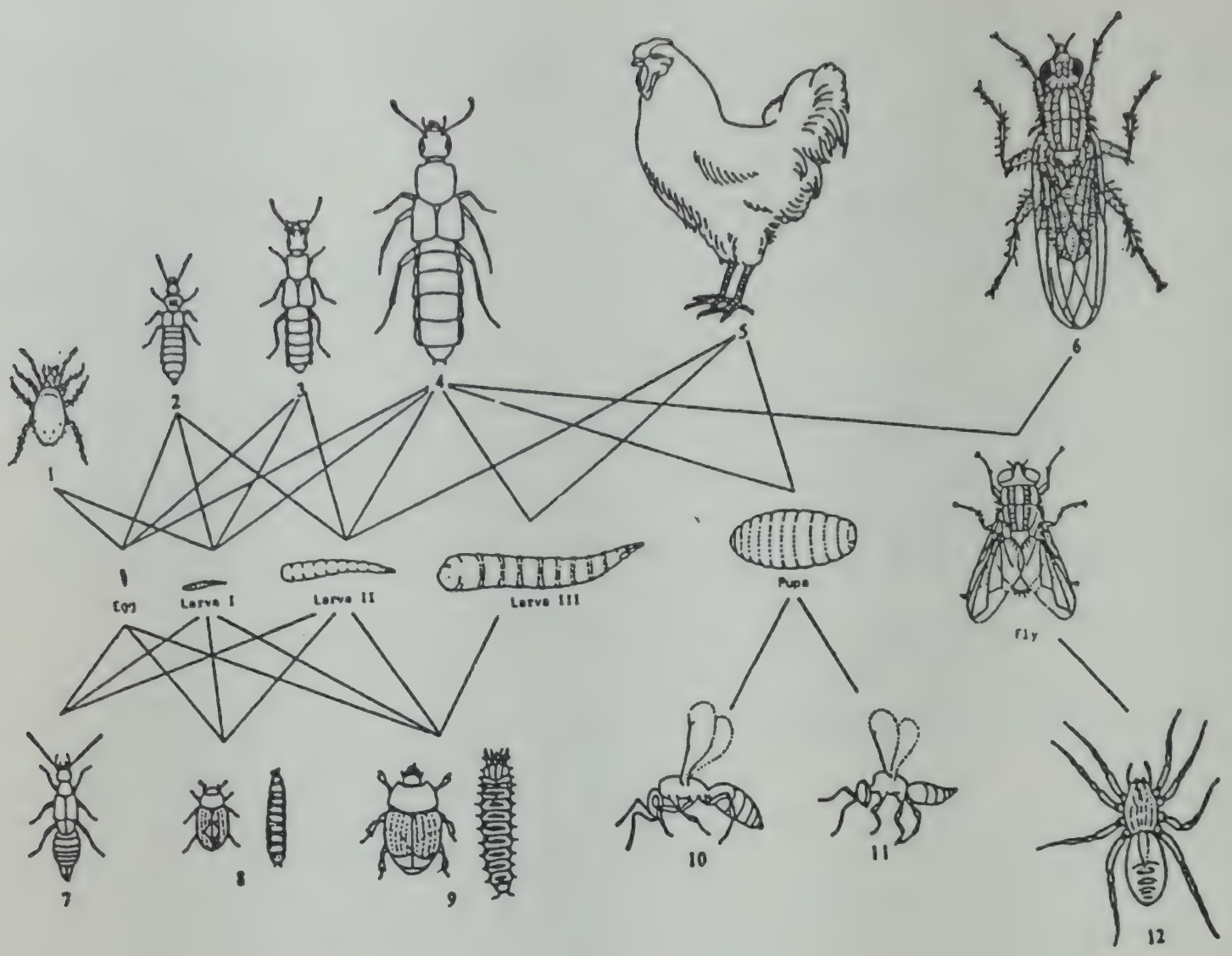


Diagram showing the housefly stages and examples of its enemies at the dung heap. The lines show the stages that are attacked by each predator or parasitoid.

Housefly stages: Egg, larva , puparium & adult.

1. Macrochelid mite
2. Staphilinid beetle: Oxytelus
3. Staphilinid beetle: Philontus
4. Staphilinid beetle: Creophilus
5. Hen
6. Yellow dung fly: Scatophaga stercoraria
7. Earwig: Labia minor
8. Hydrophilid beetle: Cercyon with larva
9. Histerid beetle: Hister with larva
10. Chalcid wasps: Spalangia
11. Chalcid wasps: Muscidifurax
12. Spider: Trochosa

Under tropical conditions around 70 to 90% of immatures of houseflies are attacked by the natural enemies present in the habitat it self. Wherever such natural enemies exist it is important to preserve them while cleaning the manure a little amount may be left to perpetuate the population of fly regulating fauna. The use of biological control agents for fly control in manure heaps illustrate that a multiagent approach is essential. In stead of depending on a single biological control agent a combination of various natural enemies and involving it at an appropriate stage will give a maximum benefit. The use of insecticides must be in a manner complimentary to these approaches.

Chemical control

Use of insecticides for fly control is an important component of an integrated fly control programme. However its role should be restricted in a manner aimed to encourage biological control agents. Some of the common chemical control measures used for the control of houseflies are described below

a) Residual treatment: This treatment is directed against surfaces in and around animal shelters, fly breeding areas, and areas where flies congregate for feeding or resting. The preferred indoor night resting sites such as edges, strings, wires etc. are to be covered by residual spray. In warm nights houseflies may prefer exterior surfaces of buildings fences, trees and shrubs. Hand operated or power operated sprayers are used for residual treatment.

b) Cords and strips: Insecticide treated cords or strips may be hung from rafters or ceilings or dwellings restaurants, poultry forms or animal stables. They are suspended under the one metre of cord is used for each square metre of floor space.

c) Baits: Baits are placed or applied in sites where adult flies congregate to feed, such as in and around poultry forms, dairies and food handling establishments. Dry baits are scattered in a thin layer by hand from a bag, shaker-top can or similar container. Liquid application can be made using a compressed air sprayer or a sprinkling can.

d) Space treatment: Indoor treatment is directed towards dwellings, kitchens, restaurants, shops, poultry farms and animal stables. Outdoor areas to be treated are refuse dumps, recreation sites, markets food industry sites, garbage containers and garbage trucks.

e) Larvicides: Larvicides can be applied at the main breeding sites of the housefly like refuse, animal or human excrement etc.,

Insecticides used for fly control:

(a) Some of the insecticides used for residual spray and space treatments and the effective concentrations to be applied for the control of flies are as follows.

INSECTICIDES USED FOR RESIDUAL TREATMENT AND SPACE TREATMENTS FOR FLY CONTROL.

INSECTICIDES	CHEMICAL TYPE	RESIDUAL SPRAY (dosage g/m^2)	SPACE TREATMENT (dosage g/m^3)	TOXICITY ORAL LD_{50}
1.DELTAMETHRIN	PY	0.0075-0.15	0.5-1.0	2940d
2.DIAZINON	OP	0.4-0.8	336	300
3.FENCHOROPHOS	OP	1.0-2.0	448	1740
4.IDOFENPHOS	OP	1.0-2.0	336	2100
5.PERMETHRIN	PY	0.025-0.05	5-10	4000d
6.PIRIMIPHOS METHYL	OP	1.0-2.0	250	2018
7.DIMETHOATE	OP	0.046-0.5	224	150
8.MALATHION	OP	1.0-2.0	672	2100
9.NALED	OP	0.4-0.8	224	430

d = Dermal toxicity

(b) Cords and strips can be treated with insecticides azamethiphos, diazinon, dimethoate, fenthion etc as solutions or emulsions at the concentrations of 100-250g/l.

(c) The insecticides used in baits are azamethiphos, bendiocarb, diazinon, dichloropos, dimethoate, naled primiphos-methyl or propoxur. Dry baits contain 10-20g/kg of the ingredient in a carrier such as sugar. Liquid bait contans 1-2g/l insecticide and sugar 10g/l in water.

(d) Among the larvicides insect growth regulator diflurobenzuron at the concentration of 0.5-1.0g/l can be sprayed against multiresistant fly larvae. Organophosphorous compounds such as bromophos, dimethoate, fenchlorophos, fenitrothion, fenthion, malathion and primiphos-methyl at the concentrations of 1.5 to 6.25g/l.

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IV Biology and Control of Cockroach

Cockroaches are an ancient and highly Successful form of insect life. So far about 3500 named species of living cockroaches have been described. A few species have become closely associated with man and his various activities and are recognized as being pest insects. However, this small number is deceptive, because among them are some of the most persistent and important pest species which impinge directly upon man and his immediate environment.

Medical importance:

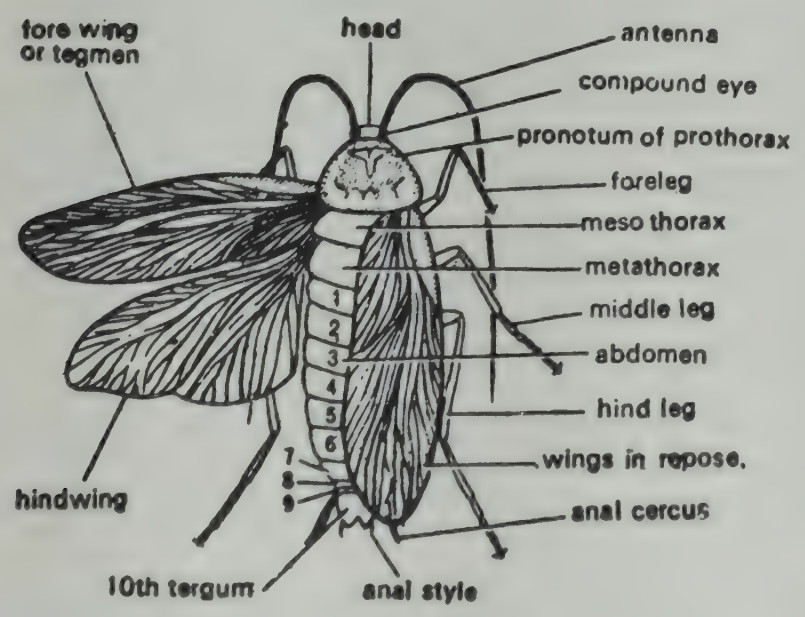
The medical importance of cockroaches is much greater than generally realized as they have been shown to harbour pathogenic bacteria, serve as intermediate hosts for pathogenic helminths and to carry helminth eggs, viruses, protozoans and fungi affecting man. Their habit of feeding both on human faeces and human food is an example of their potential health hazard to man Some examples of diseases in man caused by pathogenic bacteria, harboured by cockroaches (Vector) are leprosy, dysentary, diarrhoea, gasteroenteritis, typhoid, cholera, pneumonia, diphtheria, tuberculosis etc. They are also responsible for transmitting several helminthic infections and

infectious hepatitis. Perhaps the most dangerous feature of cockroach behaviour are their habits of regurgitating partially digested food and dropping faeces simultaneously while feeding.

Morphology of cockroach:

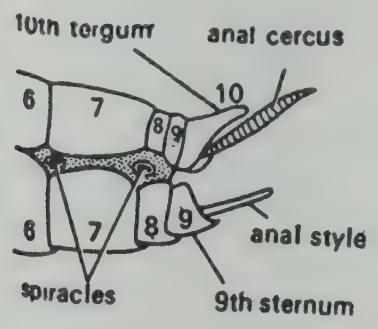
Cockroaches are flattened from top to bottom and vary in colour from tan to light brown to black , except for certain colourful tropical species. When the insect is at rest the head is bent downward and backward under the pronotum. The head has one pair of long filamentous antennae or feelers two large compound eyes and chewing mouth parts. The pronotum covers the bases of the head and wings. Typically the forewings are coloured and leather like, while the hind wings are clear and membranous.

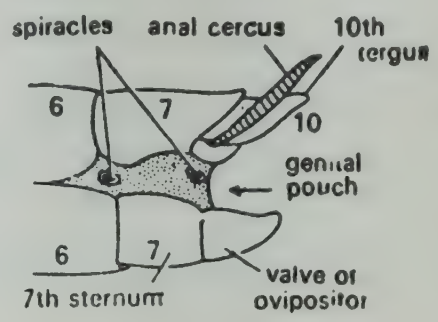
Periplaneta americana



Some species have short wings and a few are wingless.

Both males and females have large segmented cerci at the tip of the abdomen. Males differ from females by the form and shape of the last abdominal segments. The adult males generally have a more thinner longer abdomen while the female abdomen is fatter and more rounded. In addition males have styli near their cerci.





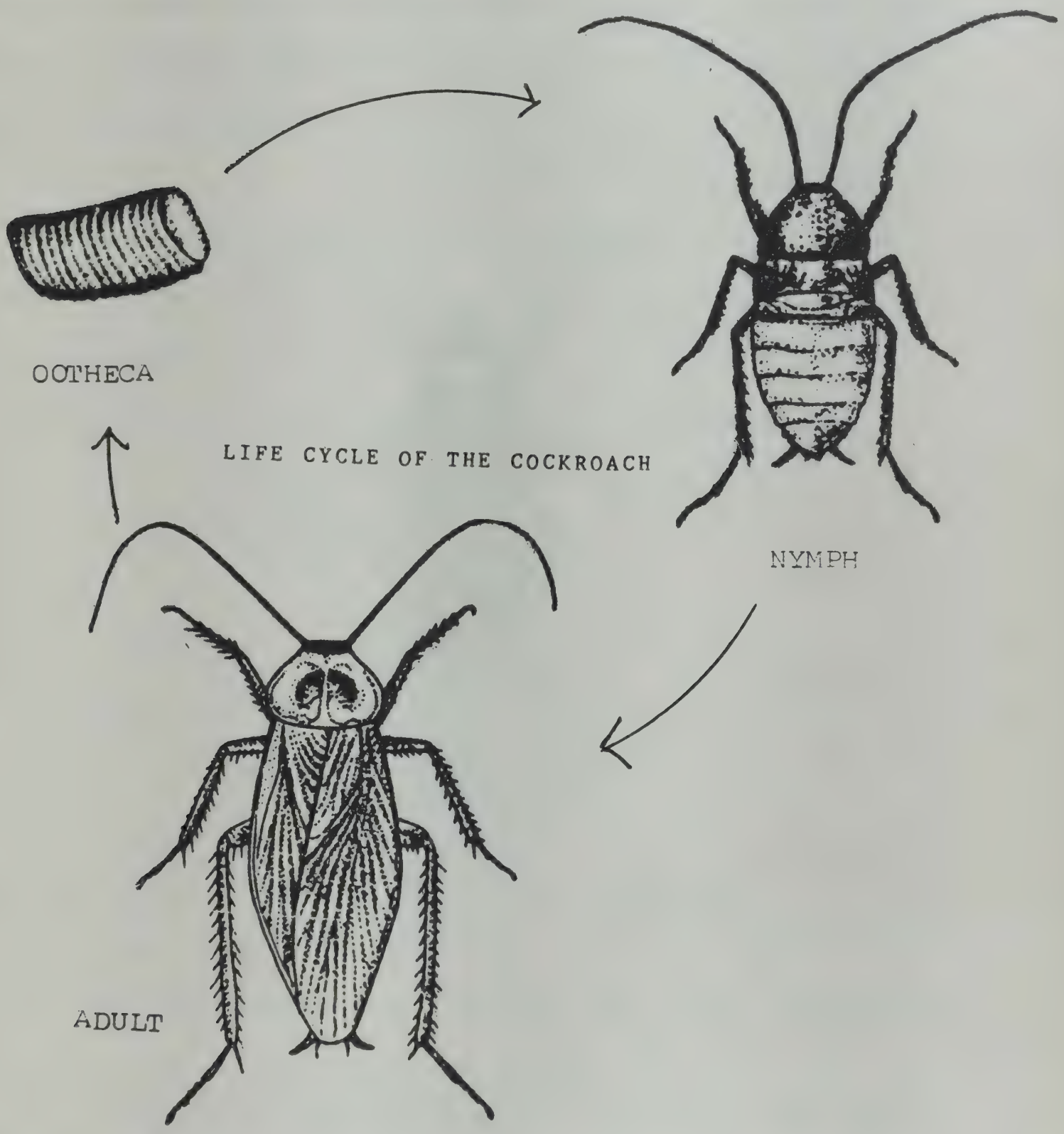
COCKROACH

MALE FEMALE

Cockroaches are active during the night time and hide during the daylight hours in cracks and crevices in walls, door frames and furniture and in secure places in bathrooms, cupboards, steam tunnels, animals houses, basements, electric devices and drains. They live in groups.

Life History: Their life cycle include egg, nymph and adult stages. Males mature faster than females. After mating an adult female produces an ootheca, every 4 -10 days. An average of 21 - 60 oothecae could be produced during its life time,and each one of these egg cases contain 16 eggs arranged in two

parallel rows. Under tropical conditions these eggs are incubated for 30 - 45 days and 7 - 13 nymphal instars (stages) over a period of 5 - 15 months have been recorded. The first few moults occur at regular intervals while the later ones may be



irregular. Production of eggs (ootheca) even without mating(Parthenogenesis) is also known to occur in this cockroach.

A few species have become used to living closely with man. Some of these will be described briefly.

The american cockroach, Periplaneta americana is found all over the Indian subcontinent,with the adults measuring 35-40 mm in length,reddish brown in colour and the two sexes can easily be differentiated by the presence of anal cerci and style in males and a stouter abdomen in females.

P.AMERICANA

P.americana can be found in sewage, kitchen, garbage, moist litter and other dirty places in and around human habitations. They are nocturnal, active during the night times and hide during the day in cracks and crevices in walls, door frames and furnitures. This wide variation in living conditions also highlights the fact that this insect can tolerate a wide range of temperature and humidity. The average life span of an individual cockroach could range from one to two years and the

maturity is attained only after one year of nymphal development. They are omnivorous, feeding on sugary and starchy materials, meat etc.

Constant associations with human habitations places these insects in restaurants, food processing plants, oil mills, grocery stores, bakeries and other places which provide them with adequate food.

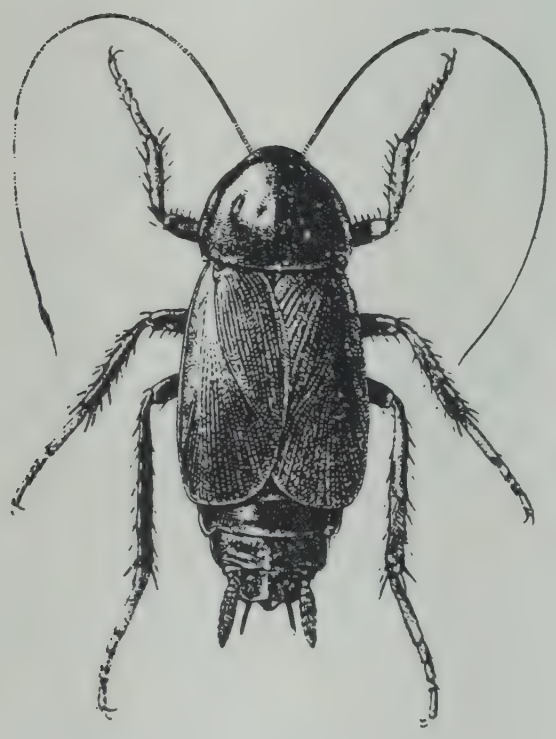
The German cockroach, Blatella germanica, is found in most places of the world and is one of the smallest domestic pest measuring 10-15 mm in length. Males are light yellowish-brown, while females are slightly darker. They are common in kitchen

B.GERMANICA

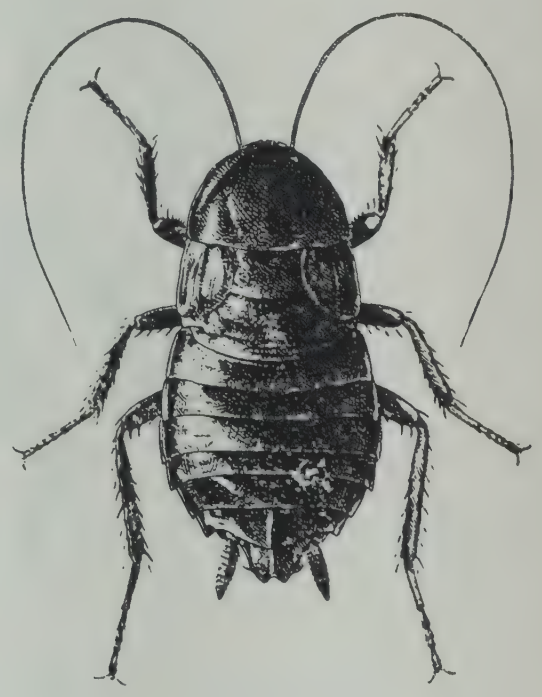
and places where food is stored. Adults of the both the sexes develop at about the same time, and usually mate within the first 7-10 days of adult life. A female produces 4-8 egg cases

during her life. Normally, egg cases vary in the number of eggs inside them from 37-44. The nymph moults 5-7 times over a period of .30-60 days. Adults live for more than 100 days.

The oriental Cockroach: The oriental Cockroach, Blatella orientalis is another important pest, but it is found mainly in the cooler, more temperate regions. It is blackish in colour and 20-27 mm in length. The female has a triangular wing pad while male has short wings. They have a strong nasty smell and are much disliked because they live in drain, sewer and other unsanitary places.



MALE

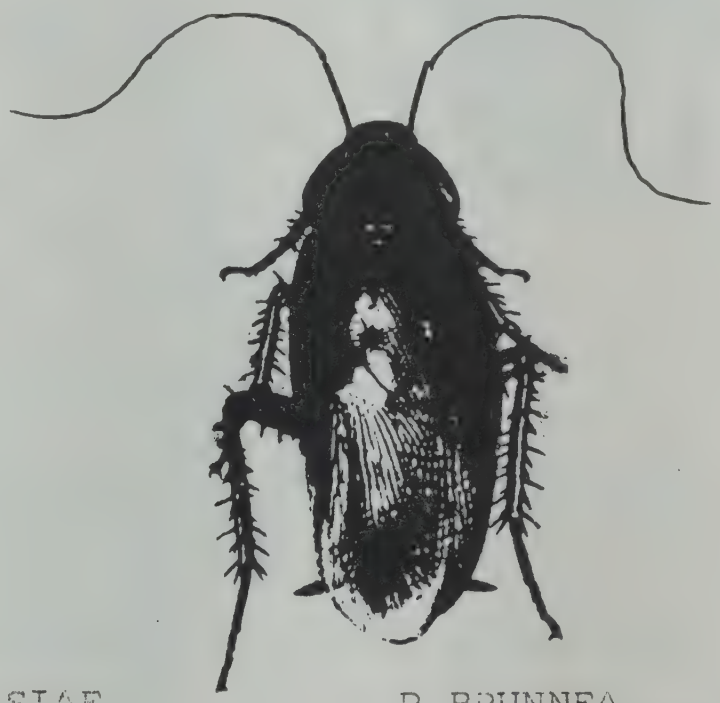


FEMALE

B. ORIENTALIS

Australian Cockroach: The Australian cockroach, Periplaneta australasiae occurs in many parts of the world. In general, it is a little smaller than P. americana and is perhaps a bit darker in colour. It has a pale yellow stripe on each fore wing extending for about one-third of its length. It has a design on the pronotum,very similar to but more distinct than that of P.americana.

P. AUSTRALASIAE

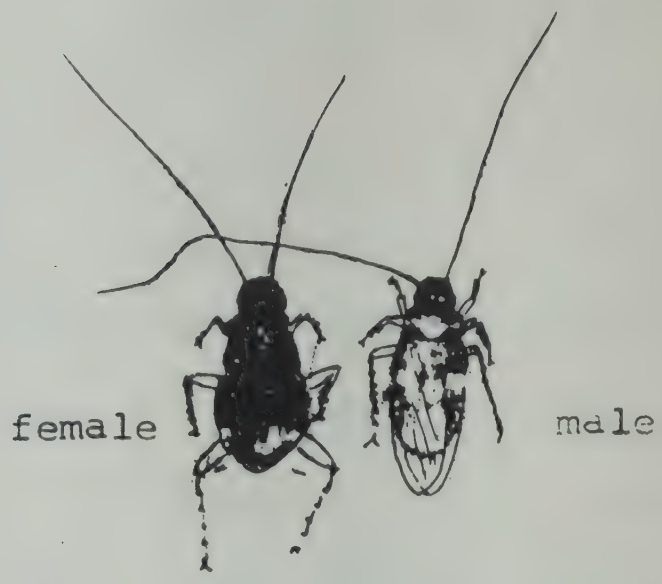


P.BRUNNEA

Large brown Cockroach: The large brown cockroach, Periplaneta brunnea appears to like warmer climates and found in kitchen, food stores and surrounding areas. It is a stout insect than the American cockroach. The marking of pronotum is very pale, but less distinct than P. americana.

Smoky-brown Cockroach: The smoky-brown cockroach, Periplaneta fuliginosa is an outdoor species mainly inhabits garages woodpiles. It is common in subtropical area . The wings are fully developed in both the sexes and the body is uniformly dark in colour.

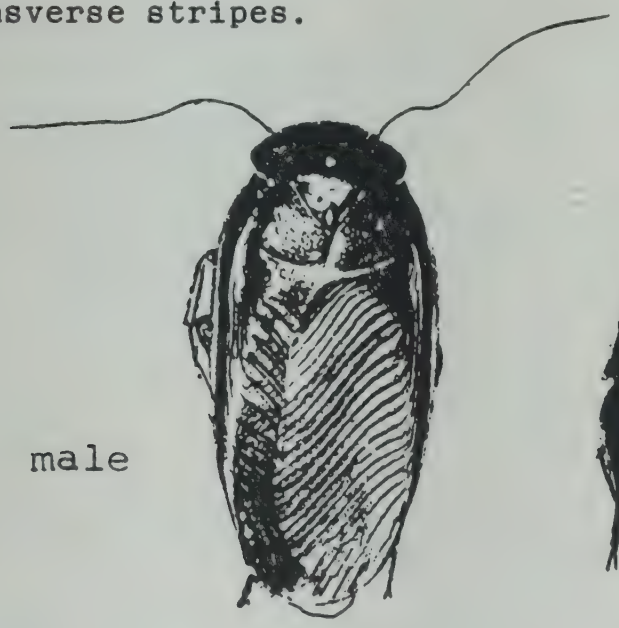
P.FULIGINOSA



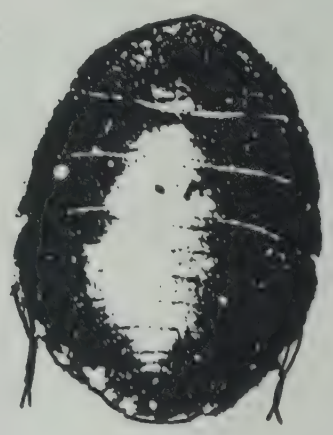
female male

S.LONGIPALPA

Brown banded cockroach: The brown banded cockroach, Supella longipalpa, is found throughout houses some times in electric clocks, radio and television sets which provide warm, dark hiding places. The female has short wings while the males with longer wings. The mesonotum has a pair of dark coloured transverse stripes.



male

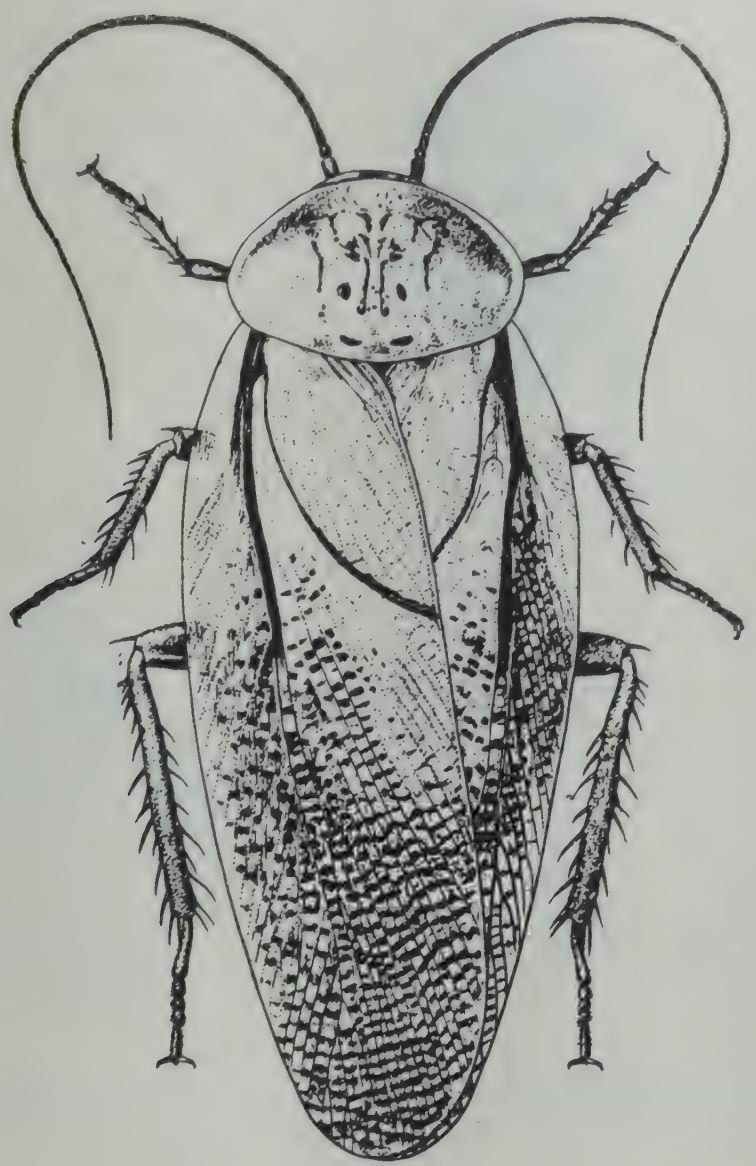


female

P.AEGYPTIACA

Polyphaga aegyptiaca : It has cosmopolitan distribution. The male is measuring 25-30 mm in length. The females are wingless and measure 25-34 mm. The body is robust

and strongly convex dorsally. The entire body is black in colour.



L.MADERAE

Madeira cockroach, Leucophaea maderae is circumtropical in distribution and the body measures 40-50 mm. in length. Wings are fully develop and usually cover the tip of abdomen in both sexes. It has mottled appearance on the posterior part of the forewing.

Harlequin cockroach, Neostylophyga rhombifolia is a strikingly coloured cockroach. The thoracic tergits are marbled with shining black and yellow colour. The length ranged

from 20-25 mm. Males are smaller than females. Fore wings are

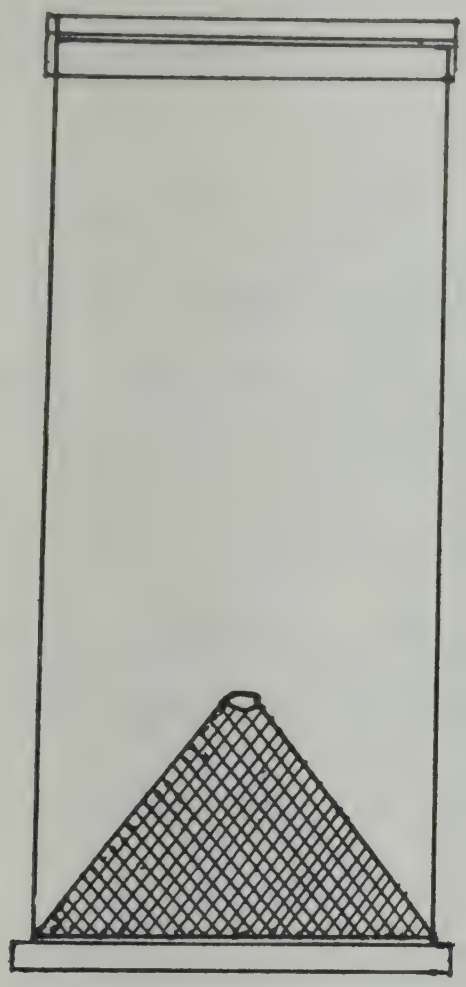
N. RHOMBIFOLIA

vestigial and hind wings are absent in both the sexes.

Cockroach Survey Method:

In order to plan and evaluate cockroach control programme it is necessary to obtain a reliable assessment of cockroach population density and their change in relation to the control methods used. It involves pre-control surveys to determine where, when and how the cockroach control should be carried out, and post control surveys to evaluate the effect and success of the control measures. To assess the cockroach density baited traps and sticky traps are being used. The baited trap is made of a cylindrical screen wire cage which consists of an inverted cone entrance at one end and a lid on the other end. The

trap is generally baited with pheromones to attract cockroaches.



BAITED TRAP

Sticky traps are used indoor habitat where adhesives and sticky tapes are being used. The density of cockroach is being monitored by counting the number of shed skins, egg cases and the stains of excreta also.

V. COCKROACH CONTROL

Prevention and control

Cockroaches enter homes are other buildings from out of door habitats or they move from nearby homes or apartments. Another important means of entry for cockroaches into houses is in infested containers of food, laundry, luggage, etc. Some common examples are soft drink cases, egg crates, and other

luggages. All packages of this kind should be carefully inspected for cockroaches before they are brought into homes.

To prevent the cockroach infestation in home conditions must be unsatisfactory for their development by keeping the kitchen and store room dry and making food and water unavailable for cockroach. Food should be stored in tightly covered containers. All areas must be kept very clean so that no bits of food or organic matters remain for cockroach. Cleanliness, reduces suitable areas for cockroach harbourages, and prevents their entry into homes.

Control by chemical insecticide

Organophosphates, carbomates, syntetic pyrethroids and organochlorines are the main type of chemical compounds used on a world wide basis, especially for residual applications. Liquid sprays are best use for cockroach control, dust of 1% bendiocarb, 2% diazinon and others are sometimes employed. Combination of dust and spray treatment may be more effective than either alone. Several chemicals may be brought as baits or poisoned food for the control of cockroaches. A powder containing 1.9% dichorvos is made up by having water added to it to form a paste. Baits are usually more effective when the size of the population is small.A list of compounds and the methods of application is given in Table-1.

Residual sprays are usually applied with a compressed air sprayer. The spray should be applied as coarse particles rather than as a mist to moisten surfaces thoroughly. Special attention should be given to application in places such as food service establishment where there is danger of contamination where only crack and crevices treatments may be legally permitted.

An aerosol or space spray may be used with an irritant or repellent which derives the cockroaches from their harbourages into areas sprayed with residual insecticides.

Ultra low volume (ULV) method is also being used in outdoor habitat, where small quantities of liquid concentrate insecticides are being sprayed, which disperse in the form of small droplets.

Dusts may be used within walls void spaces or cavities, false ceilings and other harbourage area which cannot be reached. Dust can be applied with a hand operated puff duster of bellows type.

Frequency of application

How long the deposits of insecticides remain effective depends upon a number of factors such as the chemical used, its formulation, the type of surface to which it is applied, and the

amount of wearing or rubbing off that occurs. The insecticidal deposit may be reduced by frequent washing of a surface, or it may be made nearly useless through becoming covered with dust or other material. The need for the treatment may depend upon how well the first application is carried out and the extent to which the infestation is occurring.

Precautions:

Care should be taken to avoid contamination of food or the placing of insecticides where children may come in contact with the residues. In cattle sheds and poultry farms limited use of insecticide is possible. No chemical insecticides should be used against cockroaches unless it is officially proved for that purpose.

Resistance to insecticides:

The development of the resistance to insecticides in cockroaches has occurred primarily in the German cockroach. This is due to its common occurrence and shorter life cycle and more exposure to chemicals. The occurrence of resistance to the organochlorine compounds prompted a shift towards increased use of organophosphorus and carbamate compounds in cockroach control.

Role of community in cockroach prevention and control

Control of domestic cockroaches should be organized on a community wide scale. The first effort should be directed at careful surveys. When making surveys the signs of cockroach infestation should be noted down based on the shed cockroach skins, egg cases, and stains of excreta of cockroaches. After the problem is thoroughly understood, efforts should be made to organize educational programmes to inform the community of local places infested with cockroaches and the importance of cockroaches in health and hygiene. Citizens should be aided and encouraged to reduce or eliminate cockroach harbourage sites, carry out measures to get rid of cockroaches, and improve the environmental sanitation of the home and public areas. Finally, control methods needing the use of chemical insecticides and other methods, as described above, should be carried out. By following this procedure, an integrated or combined programme aimed at permanently controlling or reducing cockroach infestations can be successful. Cockroach control is likely to remain a piecemeal affair, with only temporary reduction or riddance from individual buildings or units followed by reinfestation, unless a programme of this type is carried out.

Insecticides used in cockroach control,Table-1

Type of application	Insecticide formulation and % of active ingredient	Remarks
Residual spray	Bendiocarb 0.24-0.48% EC, diazinon 0.5% EC, chlorpyrifos 0.25-0.5% EC, Solu, malathion 3% EC, Solu, propoxur 1% EC, solu, permethrin 0.125-0.25% EC	Food Areas: Cover or remove all food. Apply in cracks & crevices. Non food areas: spray doors and windows storage areas etc.
Indoor baits	Dichlorvos 1.9%, propoxur 2%	Apply in hollow walls or on papers which will per mit removal in accessible areas.
Aerosol	Pyrethrins 0.6% + synergists	Useful for survey or spot treatment.
ULV space spray	Propetamphos 2% + dichlorvos 0.5%	Remove all food. Open all cupboards. Apply at rate of 2 g/m^3 . Allow adequa ate ventilation before human re-entry.
Indoor dusts	Diazinon 2%, Permethrin 0.5%, Bendiocarb 1%	Apply in cracks & crevices Apply in fuse boxes & other electric wires where sprays damage the insula tion.

EC: Emulsifiable concentrate; Solu: Solution.

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V BIOLOGY AND CONTROL OF TICKS AND MITES

I TICKS

Ticks and mites belong to class Arachnida, Phylum Arthropoda. Whereas insects are characterised by the presence of head, thorax and abdomen with three pairs of legs and two pairs of wings, the arachnids are differentiated by their body being divided into a prosoma and an abdomen, presence of four pairs of legs in adults and absence of wings.

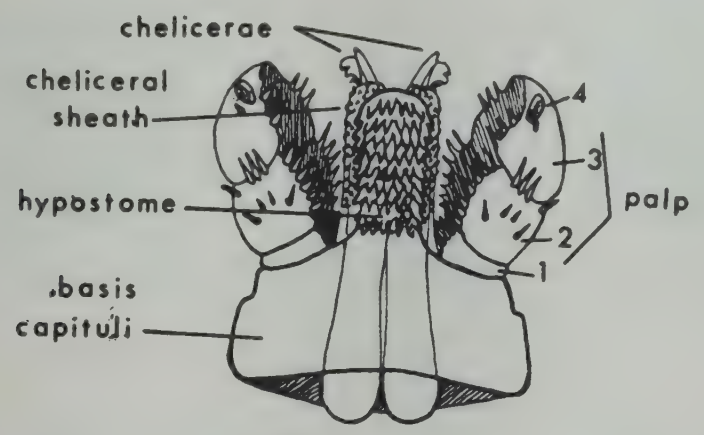
Ticks are capable of ingesting blood, sometimes even 100 times their own weight. Number of diseases transmitted by them is considerable and hence they are of medical importance.

Commonly, ticks are differentiated into hard ticks and soft ticks. The former are placed under family Ixodidae and the latter under family Argasidae.

Morphological characters of Hard ticks:

Adult hard ticks are flattened dorsoventrally and are oval in shape, measuring from about 3 - 23 mm in length depending on species and whether they are unfed or fully engorged with blood. The females are nearly always bigger than the males, and because they take larger blood meals they enlarge much more than males during feeding.

At the anterior end is the capitulum or "false head" and its base is called the basis capituli. On the base is the hypostome projecting anteriorly and has teeth arranged in rows. Tip of hypostome is called carona. The hypostome pierces into the skin and the tick remains attached to the host and feeds.



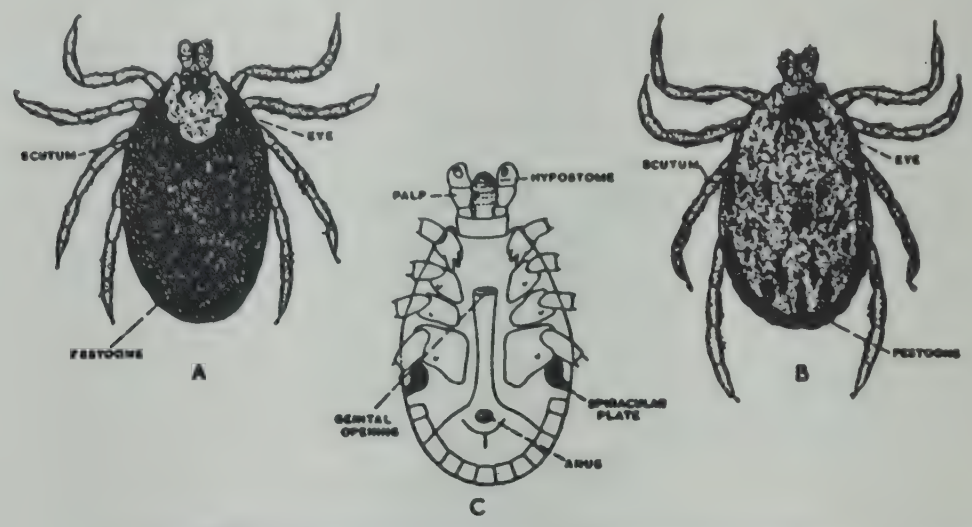
Capitulum of an adult ixodid tick showing club-shaped palps with very minute 4th segment, and denticulate cheliceral sheaths.

Immediately dorsal to the hypostome are two shaft like structures which bear cutting teeth at the anterior tip - the cheliceral shaft and cheliceral teeth. Four segmented palpi are present on either side of the hypostome. The first segment is short, second and third are moderate and fourth is situated ventrally on the third inside a depression.

The females have on the dorsal side of basis capituli two rounded areas with minute dot like structures called porose areas. This is absent in males.

All hard ticks have a dorsal plate called a shield or scutum, which is absent in soft ticks. In males the scutum is large and covers almost the entire dorsal surface of the body whereas in females it is much smaller and is restricted to the

anterior part of the body just behind the capitulum. There is a pair of grooves on it known as the cervical grooves. Median groove posteriorly and marginal grooves at side are also present.



An ixodid tick; the species depicted is *Dermacentor andersoni*. *A*. female, dorsal view; *B*. male, dorsal view; *C*. male, ventral view.

No segmentation is visible in the abdomen except structures that are considered as vestiges of segmentation called as festoons.

The eyes when present are simple. There is only light perception and no image formation.

Four pairs of legs are present in adults. They originate in the ventral side. First segment is the coxa. From coxa arises trochanter. Femur, tibia and tarsus follow. Tarsus is differentiated into protarsus and metatarsus. At the tip of the metatarsus is the pulvilli and claws. Pit like impression of the dorsal side of protarsus is the Haller's organ. This character is present in all ticks.

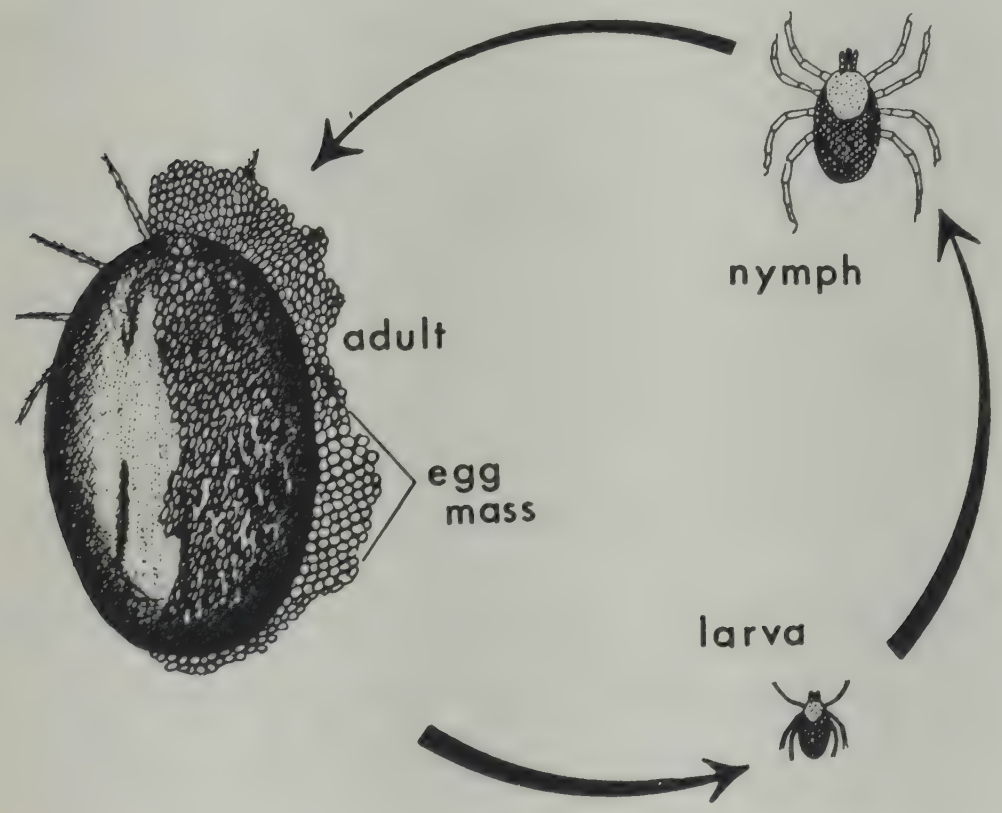
On the ventral side of the abdomen is an opening at the anterior end - the genital opening - and another one

posteriorly, the anal opening. Pair of grooves run from genital opening called the genital grooves and these may extend posteriorly. Similarly, anal groove is also present.

Spiracular opening is seen on the ventral side at the base of the fourth coxa.

In the case of males certain chitinised shields are present. They are called the ventral plates. Just lateral to the anal groove are the anal shields and there may be another pair called the adanal shields. A third pair of shields present posterior to anal shields are called as sub-anal shields.

Life Cycle:



Diagrammatic representation of the life-cycle of an ixodid tick, showing a single nymphal stage, and female with very large mass of eggs.

Consists of four stages, egg, larva, nymph and adult. Insemination occurs on the host when the male crawls beneath the female while she is attached and transfer of spermatophore takes place. After mating, large quantities of blood is ingested by the female. After fully engorging the female drops down on the ground in the resting place of the host or out in the field. It finds a suitable niche and after a gestation period, usually occupying several weeks, starts laying eggs which continues for 15 to 20 days. Fully fed female may lay anywhere from 1000 to 10,000 eggs. The incubation time of the egg is very variable lasting from a few weeks to several months depending on the prevailing temperature.

The newly emerged tick which is known as the larva measures between 0.5 and 1.5 mm. It has got only 3 pairs of legs.

The larva of an ixodid tick.

The larvae do not seek a host immediately, but remain quiescent for a few days. After this the hungry larvae seek the host actively by waving their front legs in the air. This host seeking behaviour exhibited by the larvae, and also the nymphs and adults, is called "questing". Larvae climb on to the host, attach at favourite sites like ears and eyelids and start feeding. The period of attachment varies and engorged larva

drops on the ground, seeks shelter and digests the blood and moults into nymph. The nymph, like the larva, possesses no genital aperture, but it can be distinguished from the larva by the presence of four pairs of legs. The nymph then seeks a host and gets attached and feeds, and after engorging which may take about a week to ten days drops to the ground. The blood meal is digested and the nymph moults into the adult.

The adult female closely resembles the nymph and like the latter has a small scutum, but it may be distinguished from the nymph by the possession of genital opening. The male differs sharply from both the nymph and the female in possessing a very large scutum which covers nearly the whole of the dorsal surface. In seeking a host the adult male and female behave similarly to the larvae and nymphs.

<u>One host, Two host and Three host ticks</u>:

In the life cycle of an Ixodid tick each stage - the larva, the nymph and the adult - feeds on a host. When each of the stage feeds on a different animal, three hosts are involved and such ticks are known as three host ticks. Members of the genera <u>Ixodes</u>, <u>Rhipicephalus</u>, <u>Haemaphysalis</u> and <u>Dermacentor</u> are good examples.

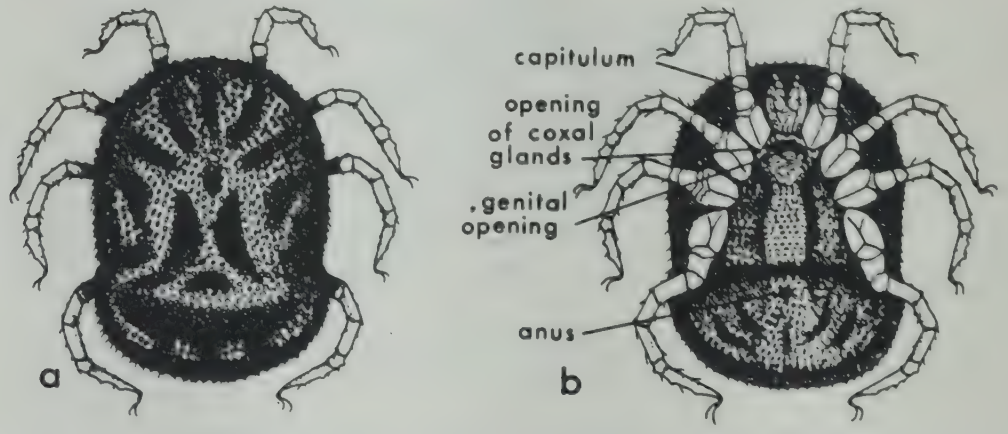
Members of the genus <u>Hyalomma</u> remain on the same host during the larval and nymphal stages, the engorged nymph dropping to the soil where it moults to the adult form which then seeks a new host; ticks possessing this type of life-cycle

in which only two hosts are required are known as two-host ticks.

A few species, notably members of the genus Boophilus, spend the whole of their larval, nymphal and adult life on the same animal, the adult female only leaving its host for oviposition. Such ticks are called as one-host ticks.

Morphological characters of Soft tick:

Argasid ticks or soft ticks are oval in shape and flattened dorsoventrally. All species of argasid ticks possess a tough, leathery cuticle with fine tubercles or granulations and devoid of plates or shield. There is no scutum. Eyes may or may not be present; when present they are situated on the lateral margins of the body.



Adults of *Ornithodoros moubata*; (a) dorsal view; (b) ventral view.

In the adult stages of both sexes the capitulum is ventrally situated and it is not visible from above. This character distinguishes the adult soft ticks from the adult hard ticks. The mouth parts are borne on the capitulum and include a pair of palps, a pair of chelicerae and a toothed hypostome.

The palps which consist of four unequal segments have their apices downwardly directed, and because of their leg-like appearance they are sometimes referred to as "pedipalps".

The genital opening is situated on the ventral surface close to the base of the capitulum. The anus is also on the ventral side and opens at the posterior end of the body.

The spiracles are located just above and in front of the fourth pair of coxae.

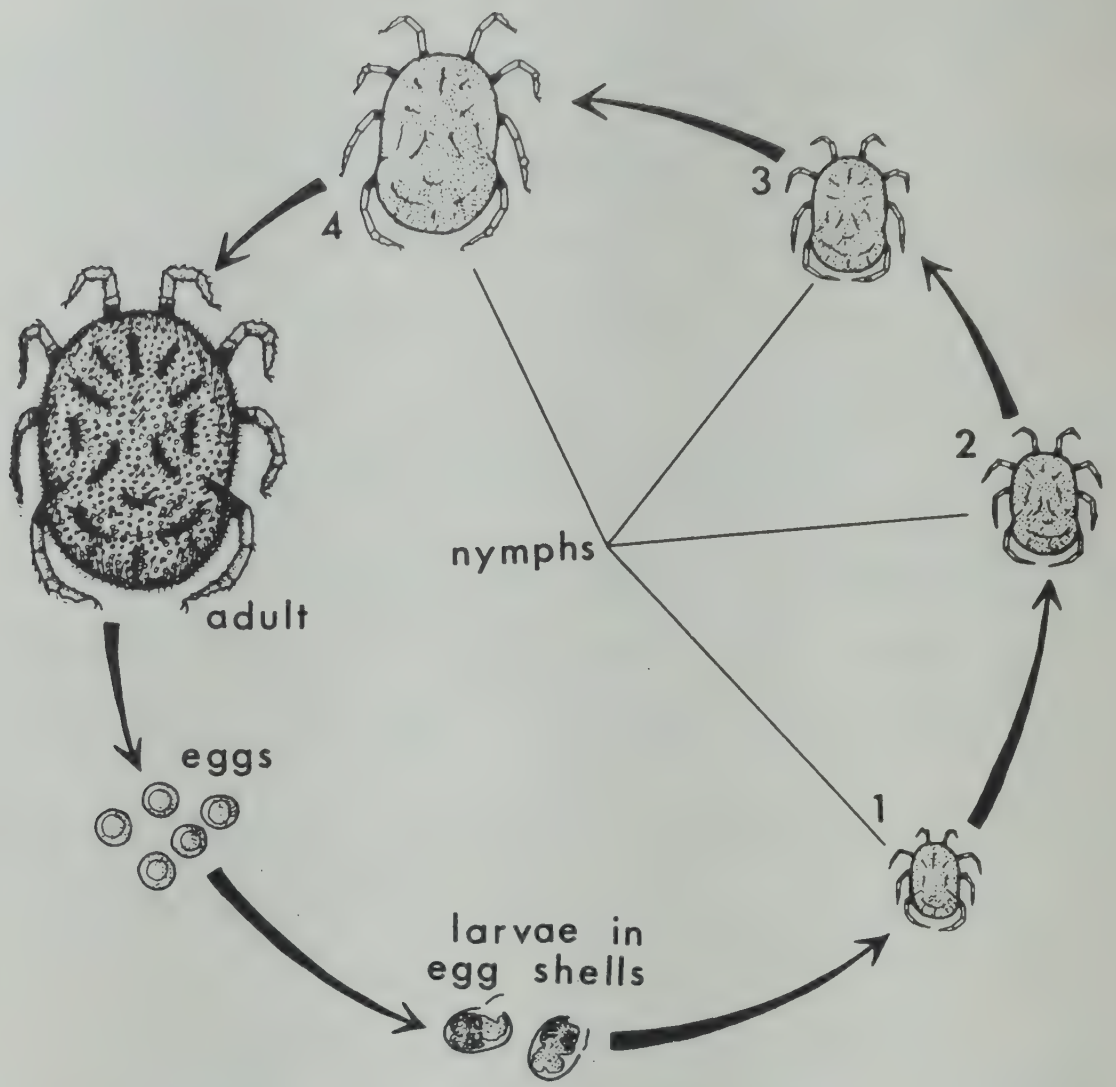
There are four pairs of legs, the segments of which are somewhat tuberculated. The tarsi lack the pads (or pulvilli) which are present in the hard ticks. The males and females are very similar in their external appearance, but they can be distinguished by careful examination of the genital aperture which in the male is more conspicuous than in the female.

Life Cycle:

Egg, larva, nymph and adult stages are present. However, unlike hard ticks the soft ticks have several nymphal stages, usually four or five. Another difference between the hard tick and soft tick is that, the female hard tick takes only one blood meal, completes oviposition and dies, whereas the female soft tick lives for several years during which it takes repeated blood meals and oviposits.

After each blood meal female argasid ticks lay several (often 4-6) small egg batches, each of about 15-100 spherical eggs. Occasionally fewer but larger egg batches comprising as many as 200-300 eggs are laid. Adult ticks can live for many

years, so a female may lay thousands of eggs during its life time.



Diagrammatic representation of the life-cycle of *Ornithodoros moubata* showing larvae retained in egg shells, and four nymphal stages.

The eggs are laid in or near to the resting places of the ticks - in cracks and crevices, in the walls and floors or just beneath the surface of mud. The eggs hatch in a weeks time or take even a month. The larva has three pairs of legs. The larva attaches to the host and feeds. It then drops to the ground and after a few days moult to produce an eight legged nymph. Four or five nymphal stages occur and each requires a blood meal. Feeding is rapid during this stage and is completed in 5-30 minutes. The final nymphal stage closely resembles

the adult but the genital opening is absent. The total length of the life cycle varies greatly and in nature it probably averages six months to a year.

Soft ticks are long lived and can survive prolonged starvation. The longevity in nature is not known but in captivity individual ticks can survive five to seven years after a single blood meal.

Medical Importance:

Although ticks are primarily parasites of animals they frequently attack man. They are a source of irritation and cause allergic reaction due to the toxic substances in the saliva.

Tick paralysis:

Females of certain hard ticks, especially Dermacentor andersoni and various species of Ixodes, Hyalomma, Rhipicephalus and Haemaphysalis can cause a condition in man, farm animals, pets and wild animals called tick paralysis. This is not caused by any pathogen but by various toxins contained in the female tick's saliva which is continually pumped into the host during the long period the tick is feeding on the host. The symptoms appear· 5-7 days after a female has started feeding. There is an acute ascending paralysis affecting the legs and as a result the person cannot walk or stand and has difficulty in speaking, swallowing and breathing, due to paralysis of the motor nerves. Symptoms are painless and there is no rise in temperature. When the ticks are removed the patient makes a full recovery

within a few days or weeks.

Besides this, ticks act as transmitters of certain protozoan, rickettsial, bacterial and viral diseases, a few examples of which are listed here.

Babesiosis: This is caused by a protozoan Babesia microtis. Basically a disease of animals but affects man. Occurs in those individuals where there is a breakdown of immune process. Mainly transmitted by Ixodes damini.

Tick Typhus: Widely distributed in India. It is a rickettsial disease caused by Rickettsia rickettsii and is transmitted by Ixodes and certain members of Haemaphysalis.

Relapsing fever: Caused by spirochaetes. Occurs in the North Western parts of India particularly Jammu & Kashmir. It is not transmitted by Ixodid ticks but by Argasid ticks, mainly by Ornithodoros. Causative organism is Borrelia duttoni.

Kyasanur Forest Disease (KFD): An important viral disease in India transmitted by ticks occuring in the forested areas of Shimoga district in Karnataka. There is a very complex natural cycle. Virus is maintained in nature in small mammals particularly some species of rodents and insectivores. Ticks maintaining cycles in them are Ixodes petauristae. Another cycle occurs in monkeys. Presbytis entellus (langur) and Macaca radiata (red faced bonnet monkey) are involved and both are

highly susceptible. The chief vector tick which transmits the virus to man is called Haemaphysalis spinigera.

Control:

Manual removal: Ticks can be removed by pulling them from their hosts. This is not very easy, especially with Ixodids, because if it is not done carefully the body comes away leaving the capitulum still embedded in the skin of the host. If this happens considerable irritation and secondary infections may result. Therefore, the capitulum is compressed and pushed deeper into the skin to loosen the grip of the teeth of the hypostome so that the tick could be removed along with the capitulum. The glowing end of a cigarette often stimulates a tick to withdraw its mouthparts. Otherwise, ticks can be coated with castor oil or medicinal paraffin, vaseline or nail varnish. This prevents respiration through the spiracles and cause them to slowly release their hold so that they can be removed; or they drop off some hours later. Often the best method to remove ticks is to dab them with chloroform, ether, ethyl acetate, benzene or some other anaesthetic before carefully pulling them off.

Use of repellents: Suitable repellents such as dimethyl phthalate, dibutyl phthalate, dimethyl carbate, butyl mesityloxide oxalate (indalone), diethyltoluamide and benzyl benzoate can be used on the skin to ward of ticks.

Alternatively, clothing can be impregnated with these chemicals, or ehtyl hexanediol, to help prevent tick infestations.

Chemical Control: Houses infested with ticks such as Ornithodoros species can be sprayed with oil solutions or emulsions of insecticides such as 5 per cent DDT, 3 per cent malathion, 5 per cent carbaryl (Sevin), 0.5 per cent naled (Dibrom), 0.5 per cent diazinon or 1 per cent propoxur (Baygon). Special care should be taken to spray floors, and cracks and crevices in walls and furniture, and any other sites where ticks may be resting.

Various insecticidal formulations can be applied to domestic pets, such as dogs, to rid them of their ticks. Recommended treatments include solutions of 0.5 per cent malathion, 0.1 per cent dichlorvos (DDVP), 1 per cent carbaryl (Sevin), 0.1 per cent dioxathion, 0.2 per cent naled (Dibrom) and 1.0 per cent coumaphos, 3-5 per cent malathion or 1 per cent trichlorphon can be applied to the coats of pets.

The dipping of sheep and cattle, and sometimes other domestic livestock, in acaricidal baths, or spraying them with insecticides, if often crucial if ticks and tick-borne diseases of man as well as of livestock are to be effectively controlled.

Problem of resistance: Intensive use of insecticides to control veterinary important ticks has resulted in ticks in many parts of the world becoming resistant to a wide range of insecticides - organochlorines, organophosphates, carbamates and even sometimes synthetic pyrethroids.

II MITES

Mites are small arachnids ranging from 0.5 to 2.0 mm in length. Majority of mites are free-living, but thousands of species parasitize animals and plants. Although parasitic mites are commonly thought of as external parasites, some species infest the inner and middle ear, the respiratory passages and lungs, skin, intestine and bladder of vertebrates. Some mites act as transmitting agents aof a number of rickettsial and viral diseases and therefore they are of medical and veterinary importance.

How to distinguish mites from ticks:

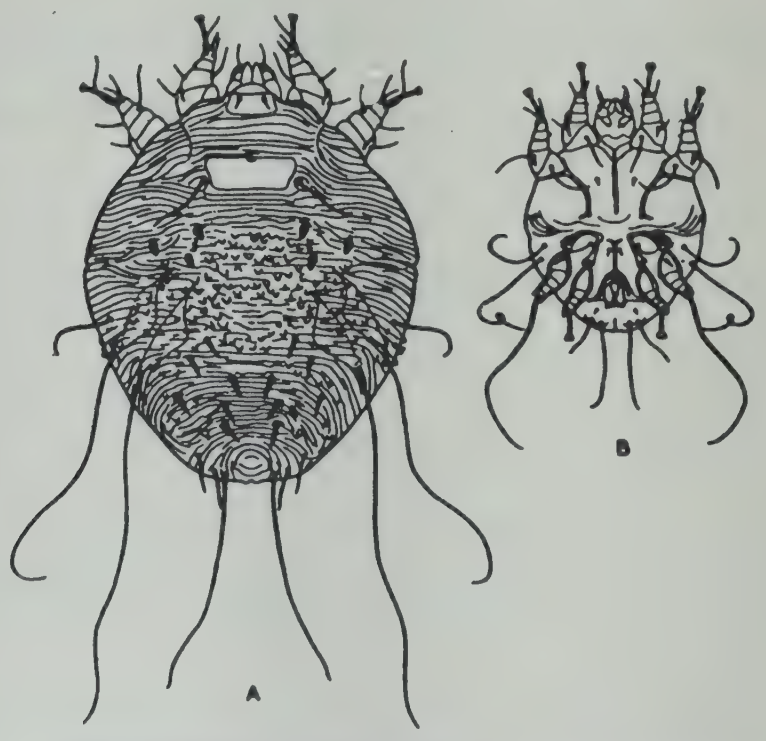
Mites can be differentiated from ticks through the absence of Haller's organ on the tarsus of the first pair of legs. The hypostome of mites is not modified as a hold-fast organ and not provided with recurved teeth. In common with ticks, mites parasitic on vertebrates are characterised as adults by having 4 pairs of legs. In contrast to ticks, many mites are free living with a wide variety of non parasitic food habits.

Two types of mites which are of medical importance are dealt with here. One causes scabies and the other scrub typhus.

SCABIES MITE: Scarcoptes scabiei var hominis are some times termed "human itch mites", since they breed only in cutanenous burrows in the skin of man.

Morphological characters of Scabies mite:

The female mite is very small measuring 0.30-0.45mm. It is whitish and disc-shaped. On the dorsal side it is covered with numerous small peg-like protuberances and a few bristles, and both dorsally and ventrally there are a series of lines across the body giving the mite a striated appearance. Adults have four pairs of short and cylindrical legs. The legs are divided into five ring like segments. The first two pairs of legs end in short stalks called pedicels. At the tip of this is a roundish structure called sucker. In the females the posterior two pairs of legs do not have suckers but end in long and very conspicuous bristles.



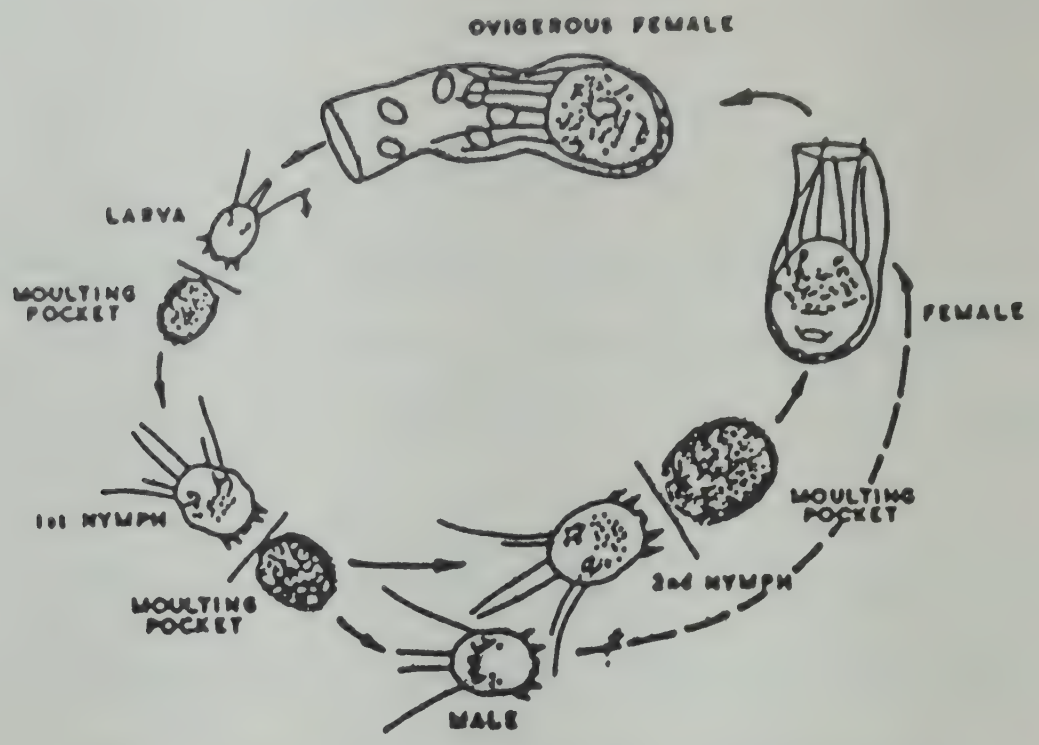
Sarcoptes scabiei. *A*. female, dorsal view; *B*. male, ventral view.

There is no real distinct head, but the short and fat palps and pincer-like chelicerae of the mouthparts protrude anteriorly from the body.

Adult male scabies mites are only about 0.20-0.25mm long, They are different from the females not only in being small but also by the presence of suckers on the last pairs of legs.

Habitat-The fertilised females make their major burrows in the human skin chiefly where it is thin and folded ie. between the fingers and toes, on the backs of the hands, the front of the wrist, the elbows, the waist,beneath the breasts, in the groin, on the scrotum, the shoulder blades, the knee etc. The burrows may be extended in length at the rate of 2-3 mm/day, until a total distance of some 15 mm may be covered.

Life history- It is believed that the male mites locate and fertilize the female on the surface of the human skin. The females wander in search of a suitable ovipositional site and the gravid female develops 1-2 eggs at a time within her body. She lays about 40 large, ovoid transparent eggs behind her in the burrow. The eggs hatch in three to five days. The larvae are six legged and moults after 2 to 3 days.



The life-cycle of a sarcoptid mite.

The nymphs are eight legged and there are two nymphal stages. The immature non -reproductive nymphal stages are smaller in size but morphologically similar to the adults. The complete life cycle requires less than four weeks.

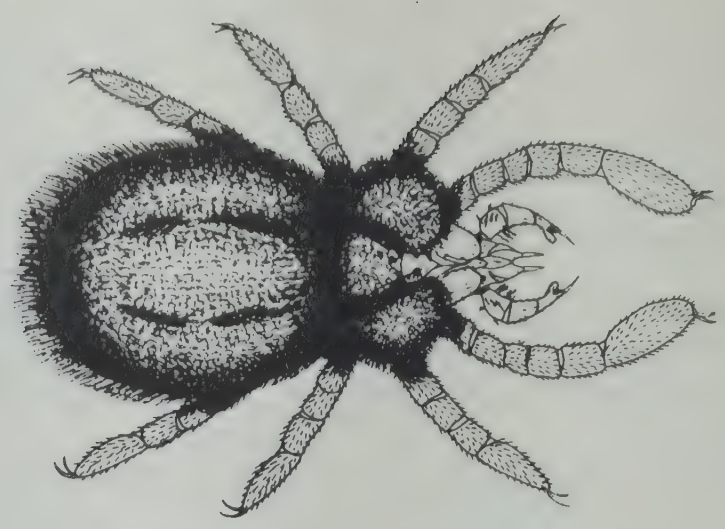
Scabies is caused partly by the adult females mites eating and scraping major burrows in the human skin and causing itching by their acid secretions and defaecations and also partly by the secondary burrowing of the male and young females. The chief cause of the irritation, however are believed to be due to an acquired sensitivity leading to secondary infections by scratching. Sensitivity to the parasites usually develops in about a month in persons previously uninfested. In persons who have suffered an

attack in the past, the itching develops within 24 hours of a new infestation. The first signs are reddish, slightly elevated tracts on the skin, leading from minute orifices to the whitish oval females below the skin at the blind end of the burrow. The lesions develop very rapidly as the breeding rate is high, so that in due course of time the skin develops multiple papules, vesiculations, pustules and secondary infection through scratching.

SCRUB TYPHUS MITE: This is a Trombiculid mite and the larvae are called as chiggers. Leptotrombidium deliense and L.akamushi are the mites transmitting the disease caused by Rickettsia tsutsugamushi. It should be noted that only the larval stages of the scrub typhus mite is dangerous since it is the one that feed on blood and is therefore capable of transmitting the disease.

Morphological characters of scrub typhus mite:

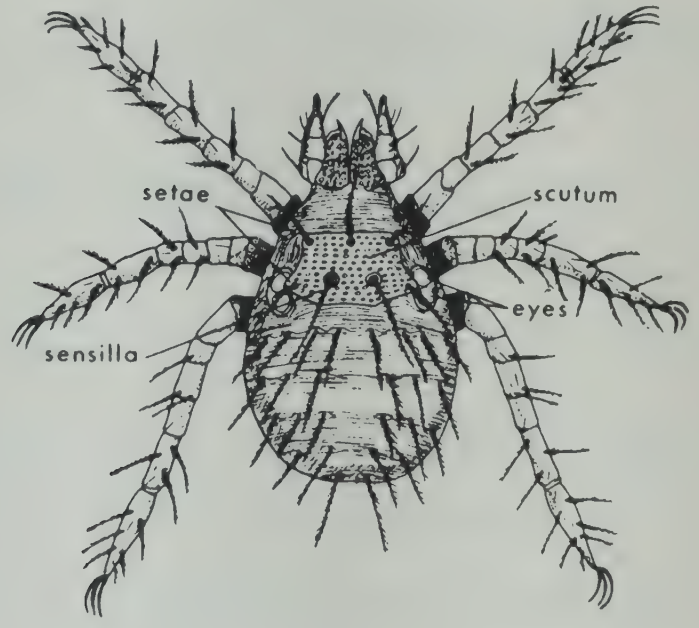
Adults are small measuring 1.0-2.0mm. Usually they are red and covered dorsally and ventrally with numerous feathered hairs giving them a velvetty appearance. There are four pairs of legs ending in paired claws. The body is distinctly constricted between the third and fourth pairs of legs giving it an outline resembling a figure of eight. The palps and mouthparts project in front of the body and are clearly visible from above.



Dorsal view of an adult trombiculid mite of the genus *Leptotrombidium*.

The nymph resembles the adult but is smaller (0.5-1.0mm) and the body is less densely covered with feathered hairs.

Larvae are very small (0.15-0.3mm), but after engorging they may increase sixfold in size. They are usually reddish or orange but may be pale yellow or straw



Dorsal view of a larval trombiculid mite of the genus *Leptotrombidium*.
Note scutum, paired sensillae and five scutal setae.

coloured. There are three pairs of legs which end in a pair of large claws. Both legs and body are covered with

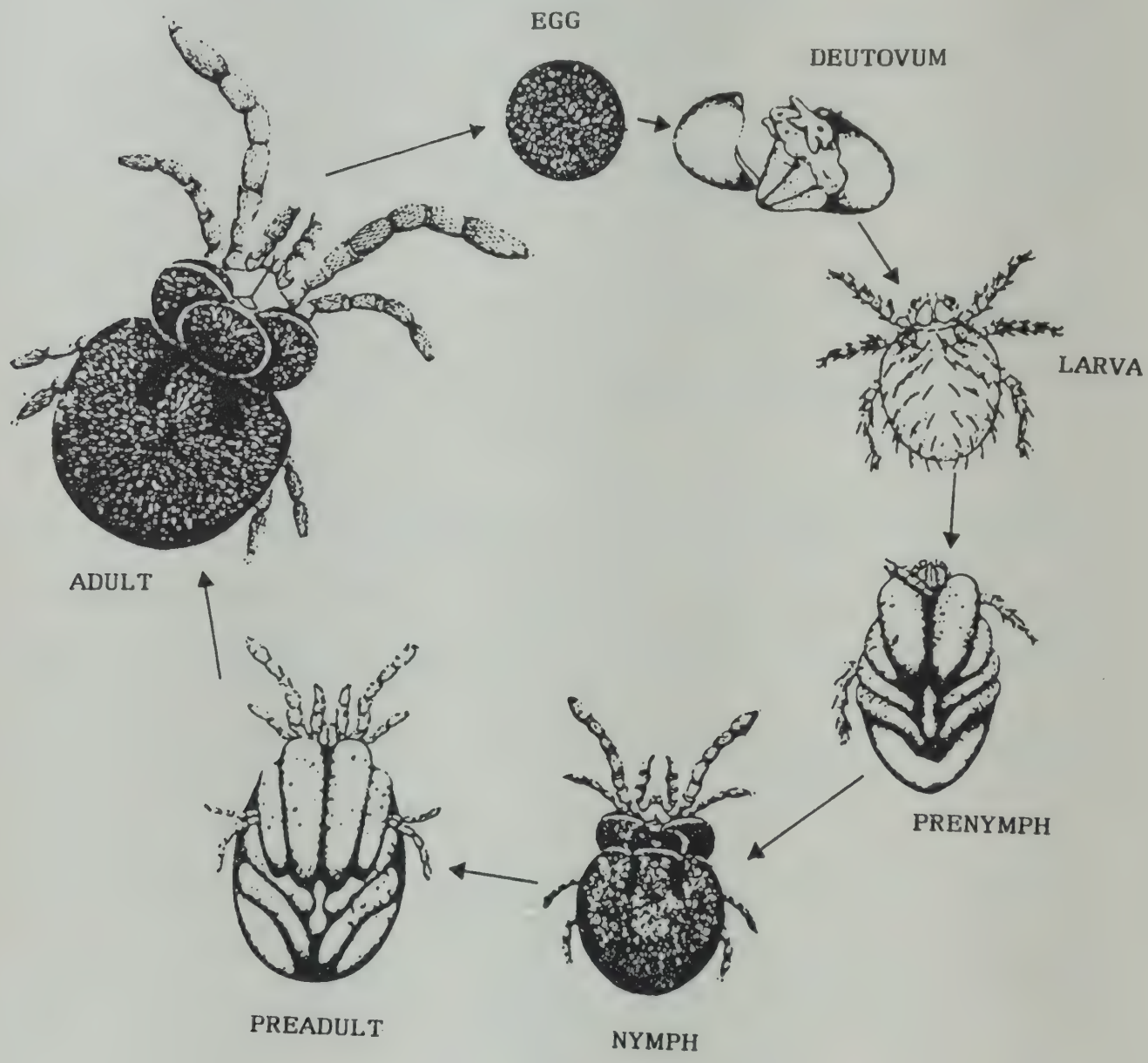
fine feathered hairs. The five segmented palps and mouthparts are large and conspicuous. Dorsally and on the anterior part of the body there is a rectangular or pentagonal shaped scutum bearing setae.

The larva of Leptotrombidium can be differentiated from others by the presence of a body covered with feathered hairs, five scutal hairs, a pair of flagelliform sensillae and large pigmented eyes.

Life Cycle:

The trombiculid mites are oviparous and deposit their eggs on the ground or leaves of low grass or bushes. A female mite lays one to five spherical eggs each day and egg laying continues for even a year in hot climates. After an initial egg stage of four to five days, the eggshell cracks in half, but the larval mite remains in a quiescent phase within the egg for a short period. This is called the prelarval or deutovum stage. Then the six legged larva escapes and actively searches for a suitable host. These larvae can survive for about one to two weeks without food. Usually the larvae (chiggers) congregate in a shaded area near the tip of a blade of grass or a fallen leaf. There they remain quiescent until a vertebrate host comes along, then after prolonged feeding, the engorged larvae leave the host and drops to the ground. It is again inactive and is called as the protonymph. After 7-10 days the protonymph moults to produce an eight legged nymph.

After a period of some days to about 2 weeks the nymph ceases feeding and becomes inactive when it is called a preadult. This moults into the adult after about 14 days.



LIFE CYCLE OF TROMBICULID MITE

The life cycle usually takes about 2-3 months but may be as long as 8-10 months.

Control:

Control procedures for mites vary considerably. Chlorinated hydrocarbons are very effective in killing chiggers on the ground. Dieldrin, fenthion, lindane, malathion and propoxur are used and may be applied as emulsions, suspensions or dusts. Hand operated or power operated sprayers or dusters can be used for the application of dieldrin at 2.8kg of a.i./ha, lindane at 5.6kg of a.i./ha, and propoxur at 1.1kg of a.i./ha.

Removal and burning of ground cover, followed by scraping and ploughing the top soil, render the areas unsuitable for chiggers.

Use of insect repellents such as dimethyl phthalate, diethyltoluamide, dibutyl phthalate, ethyl hexanediol and benzyl benzoate may be of help in reducing the likelihood of people getting infected with mites. Clothing can also be impregnated with suitable repellents.

VI PESTICIDE APPLICATION & TECHNIQUES

Pesticides play a leading role in controlling insects causing public health problem or nuisance and continue to be the major component of Integrated Vector Management (IVM) approach in which all available control techniques like biological, physical, environmental and chemical methods are blended to minimize the pollution to the environment.

TYPES OF DIFFERENT APPLICATION TECHNIQUES:

Effective application of any control measure must be based on a fundamental understanding of the ecology, bionomics and behaviour of the target species and its relation to its host and environment. In selecting a pesticide and suitable formulation, consideration should be given to the biological effectiveness against the pest concerned, the susceptibility status of target organism and any hazard to man and his environment. Consideration should also be given to the cost of the pesticide, transportation requirements and availability of equipment for applying it. The hazard of a compound is directly related to the way it is used. The pesticide application and techniques depend on the choice of the suitable formulation and selection of appropriate equipment to achieve the desired result.

The types of application technique depend on the stage of the target organism against which control measures are taken.

Larvicides:

The pesticides used in the control of immatures of vectors are known as larvicides. Pesticides are generally formulated as emulsifiable concentrate (EC). This formulation is the concentrated oil solution of the technical grade material (20 to 80% of the active ingredient) containing an emulsifier (a surface active agent which stabilizes the suspension and dispersal of one liquid in another). The emulsifier enables the concentrate to mix with water for spraying. The opaque emulsions with EC formulation are generally stable for several hours and do not leave powdery residues or clog or excessively wear spray equipment.

Sometimes the pesticides for larval control are also formulated as granules which are made by spraying a solution of 2 to 20% of the active ingredient in a volatile solvent onto a presized granular carrier. These granules are easy to apply and do not drift. Granules are also known for slow release of the active ingredient and effective for a longer period.

Residual application:

Pesticides used for application on different surfaces so as to cause mortality in resting insects for a sufficient length of time are called as residual insecticides. Generally

pesticides used for indoor residual treatment are formulated as water dispersible powders (WDP). This formulation generally contains 25 to 75% of the active ingredient which has been ground to a fine powder and mixed with a fine clay-like diluent or carrier. Since the suspension with WDP formulation is unstable, the suspension must be agitated to prevent settling and to ensure that proper concentration and effectiveness are maintained.

Space spray:

The space spray of pesticides using specialized formulation known as aerosols or ultra-low volume (ULV) formulations is generally used to achieve the speedy reduction of the vector population especially during epidemics.

Aerosols are pressurized mixtures of insecticidal chemicals in a propellant. Small amounts of aromatic petroleum solvents prevent crystallization in the nozzle and deodorized kerosine helps regulate particle size.

Ultra-low volume (ULV) refers to both the formulation and the application technique. The formulation is usually undiluted solid or liquid technical grade material that is applied in an extremely fine spray. Ultra-low volume insecticides are often useful in treating large areas and may be applied by special equipment.

The majority of pesticides used in vector control are applied in liquid form. The material must be delivered not only at the desire rate of application but also in a distribution of suitably sized droplets. There are many types of dispersal

equipments available for producing desired droplet size. Generally sprays are classified according to the volume median diameter (VMD) of droplets and the spray equipment used for producing such sprays as follows:

Name of spray	Range of droplet spectrum	Equipment used
Aerosols	1 - 50 um	Microsol & Fogging machine
Mists	50 - 100 um	Mist blower
Medium spray	250 - 400 um	Micron sprayer
Coarse spray	>400 um	Hydraulic sprayer

EQUIPMENTS FOR VECTOR CONTROL

Insecticides will be effective only if applied precisely by the most efficient applicators. Equipment selection should be based on the type of pesticide to be applied and the size and scope of the spraying job involved. Five key factors should be considered when selecting applicator equipment.

1) Will it do the job? (Effectiveness)

2) Is it safe? (Safety)

3) Is it offensive? (Public relations aspects)

4) Is it expensive? (Cost)

5) Is it durable? (Durability)

An important consideration in the selection of spraying equipment is the size of droplets produced by the equipment

during normal use. The equipment for the production of fine and coarse sprays generally comprise of nozzles and pumps. The knapsack sprayer, compression sprayers and stirrup pumps are most commonly used in vector control programmes.

Equipments for the application of larvicides and residual insecticides

Knapsack sprayer (Fig 1):

These are carried on the back and a shield is provided so that it does not come into actual contact with the back. A skirt is usually fitted to the bottom of the container to prevent the direct contact with the ground.

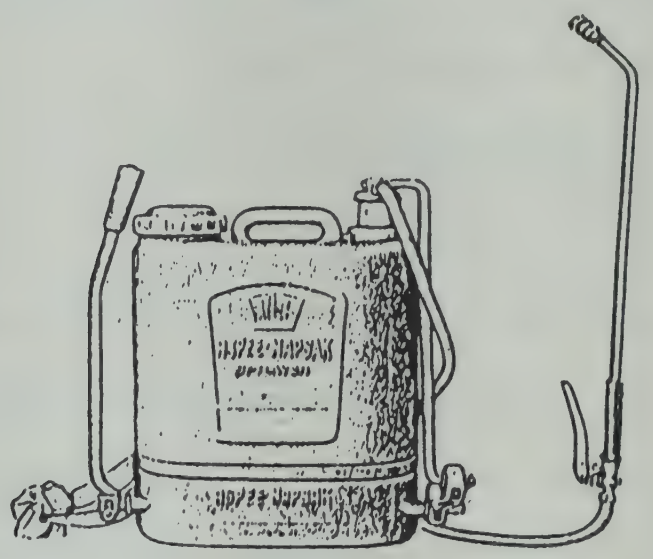


FIG.1

In knapsack sprayer, the pressure is produced by a pump that converts the mechanical energy to hydraulic energy which is the driving force for the atomization of spray liquid into desired droplet size. Generally two types of cone nozzles (solid or hollow cones) or flat fan nozzles are used in this type of sprayer. Knapsack sprayer is a continuous type of sprayer and the discharge rate is fairly constant. The sprayer can be used

by unskilled operators with little education. Maintenance is usually simple.

The operator has not only to bear the weight of the sprayer but also simultaneously operate the pump lever with one hand and direct the spray with the other. Lighter the equipment and lesser the effort needed for operation, the better will be the spray application.

Compression sprayer (Fig 2):

This equipment is simple to use and versatile for vector control purposes. However as the liquid is discharged from the

FIG.2

container, the air space increases in volume and the pressure falls. It is therefore necessary to pump air to maintain a steady working pressure.

Stirrup pumps (Fig 3):

These sprayers are widely used in vector control programmes because they are less costly than compression sprayers. They can be used with any type of hydraulic nozzle.

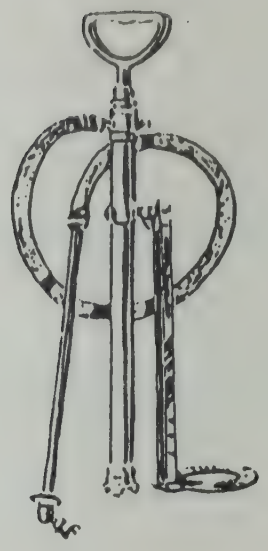


FIG.3

These sprayers consist of pump, attached discharge hose and spray lance; the pump being provided with a bracket and foot-rest or stirrup. The discharge outlet is usually placed at the top-end of the pump and should be preferably sloped downwards to prevent the delivery hose from bending or collapsing. The spray discharge is continuous because an air chamber maintains spraying pressure. This type of sprayers needs two operators, one for pumping while the other can direct the spray.

Equipments suitable for space spray:

These are either operated electrically or through internal combustion engines. Different type of equipment is necessary for thermal fogging and cold aerosol spraying.

Thermal fogging equipment (Fig 4):

For exterior fogging,the hand-carried thermal fogger generally called as Swing-fog can be used. In this machine, oil is injected into the exhaust gas of a pulse-jet internal combustion engine at a point where it will be completely vaporized and then immediately discharged.

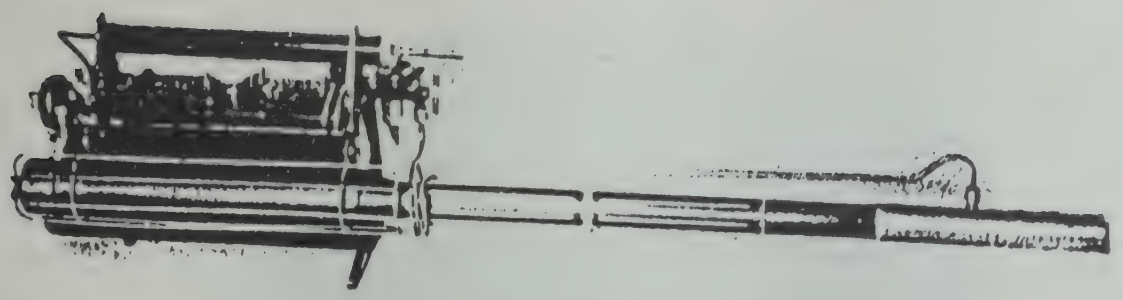


FIG.4

Devices employing this method can be hand- or shoulder-carried. But in view of the fire hazard and the possibility of misuse of diesel which is generally used, the cold aerosol sprays are preferred.

Microsol (Fig 5):

This is electrically operated for producing cold aerosol spray. In this applicator, vortical nozzles are employed wherein the air stream is given a rotary motion. This considerably increases its shearing action on the liquid so producing droplets in the size range of mists and aerosols. Because of the large orifices in the vortical nozzles, the problem of blockage is minimal. The popularity as a means of producing aerosols has grown to such an extent that they are replacing the thermal devices that have hitherto been used for this purpose.

FIG.5

Mist Blower (Fig 6):

Power-operated gaseous energy sprayers, or mist blowers consist of four main parts: a power source which can be either

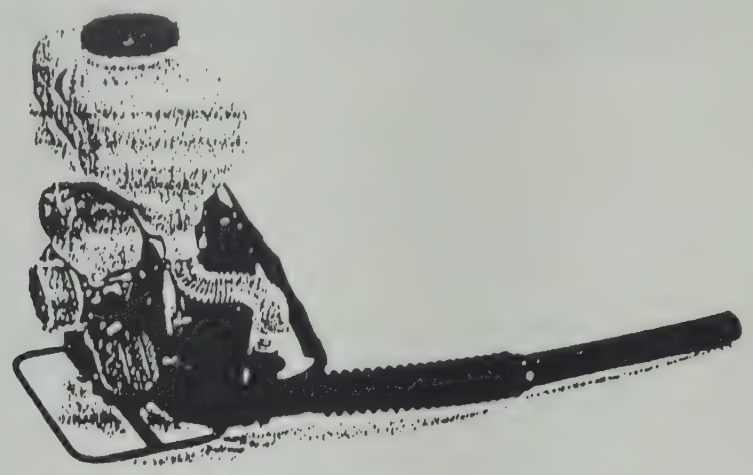


FIG.6

operated electrically or by internal combustion engine, a fan or blower, a pesticide container and a nozzle. The use of restrictors with small bores in the liquid feed permits the mist blower to be used for ultra-low-volume applications requiring a high air-to-liquid ratio in order to achieve the most effective atomization of the liquid.

LECO ULV Generator (Fig 7):

These generators overcome many of the shortcomings with thermal fogging machines. The equipment consists of a power-driven high-performance blower to supply the air, a container and a pump for the spray liquid and a directional head in which several smaller nozzles are mounted on a T-shaped head to give a wide swath discharge. These can be mounted on a trolley or vehicle. They are less noisy in operation than the thermal fogger and there is less likelihood of creating a traffic hazard.

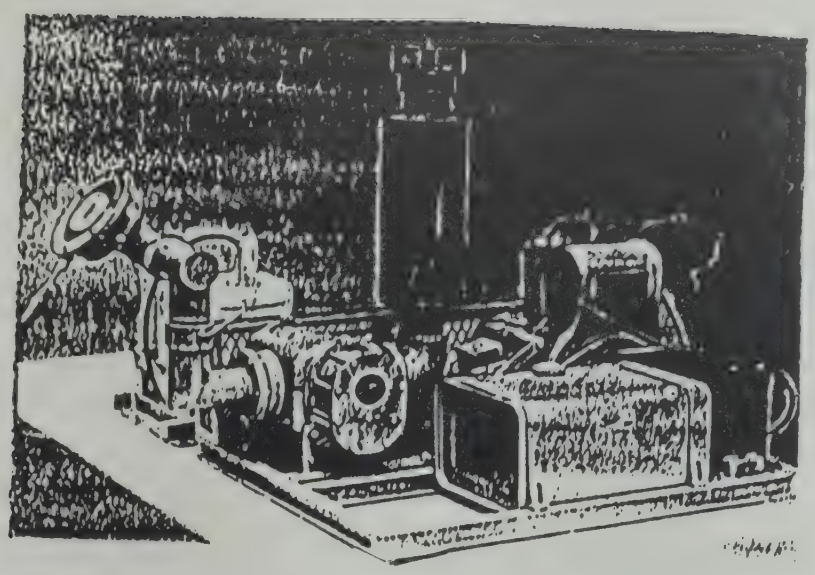


FIG.7

Care and Maintenance of Spray equipments:

All applicator equipments require diligent care if they are to be kept operating properly. Several basic rules should be followed in the care of a sprayer.

1. Handle it carefully.
2. Keep it clean.
3. Strain the formulations through proper filters.
4. Rinse it out thoroughly with water after use and pump 1 litre of water through it.
5. Every 3 months, disassemble it completely, put small metal parts into kerosene, allow to set, clean with a small bottle brush, soak nozzles, spray lance and tank with trisodium phosphate solution (washing soda), and clean with a scrubbing brush, then rinse thoroughly. Replace worn gaskets, broken parts etc. Reassemble it. Pump clean water through it.

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Maintenance of power operated equipments:

1. Power equipments should be covered when not in use.
2. Have regular preventive maintenance on all motors.
3. Replace damaged parts immediately.
4. Allow only experienced personnel to operate power equipment.

METEOROLOGY AND VECTOR CONTROL

An important factor pertinent to the physical, biological and chemical aspects of controlling vectors is the micrometeorology/overall climatology of the application area. The basic meteorological parameters involved are :

1. Temperature and temperature gradient or temperature change with altitude
2. Wind velocity and velocity gradient with altitude
3. Wind direction with respect to downwind hazards and
4. relative humidity as it relates to spray drop evaporation which occurs with respect to water and other diluents and carriers used in the liquid spray.

Ideal conditions for pesticide spray operation:

Laminar or viscous flow is encountered only under very stable or marked inversion conditions - those calm or near-calm conditions of clear evening, night-time or early mornings when

radiation from the ground causes the surface to cool below the temperature of the air so that buoyance is eliminated. Normally spray operation with the ground equipment should be done in the same direction of wind to minimize the exposure of the sprayman to the pesticide with the wind speed not exceeding 4 km/hr. But during aerial spraying, the operation should be carried out in the opposite direction of the wind.

SAFETY ASPECTS DURING SPRAY OPERATION

Routes of entry of insecticides

By Mouth: Dusts and sprays entering mouth during applications.

Drinking pesticides from unlabelled or contaminated containers.

Using the mouth to start siphoning of liquid concentrates

Eating contaminated food.

Transfer of chemical to mouth from contaminated cuffs or hands

Drinking from contaminated beverage container

Through the skin: Accidental spills on clothing or skin

Dusts and sprays settling on skin during application

Splash or spray in eyes and on skin during pouring and mixing

Spraying in wind

Contact with treated surfaces

Children playing in discarded containers

Maintenance - repair work on contaminated equipment

By breathing : Dust, mists or fumes

Smoking during application or

Contaminated smoking supplies

Inoculation : Through cuts, abrasions and rashes of the skin

Hazard in relation to handling pesticides

Hazard is generally defined as the the risk of poisoning arising in handling the pesticides in practice. Thus the most toxic insecticides may be handled with little hazard if sensible and disciplined adherence to good practice becomes routine. Hazard is a function of two other variables besides toxicity, contamination and time and is expressed by an equation.

Hazard = Toxicity x Contamination x Time

where Hazard is the risk of poisoning

Toxicity is the ability to cause damage

Contamination is the prerequisite for entering body

Time is the duration of contact with insecticide.

Hence, if any one of the three variables on the right side is zero, the hazard will also become zero. Hazard due to

the handling of the insecticide can be minimized by reducing the variables on the right side of the equation.

Toxicity

Toxicity is an innate capacity of a chemical to cause damage and may be expressed in terms of LD_{50} (mg/kg) as (i) oral toxicity, the reaction following ingestion of the material by mouth; and (ii) dermal toxicity, the reaction caused by absorption of the chemical through the skin or other tissues.

Methods of reducing risk:

The selection of a proper pesticide is a prime requisite for any effective vector control programme. In this regard, four main factors, cost, efficacy, safety and acceptability should be considered. The user is therefore intended to select the insecticide that is most effective, economical and acceptable to the community. The relationship between mammalian and pest toxicity usually offers a better indication of risk, i.e., the higher the ratio between the mammalian and pest LD_{50} s, the lower the actual risk to man.

The hazard in handling the pesticide in relation to toxicity can be reduced by:

1. Selecting material of favourable mammalian versus insect toxicity ratio,
2. Using insecticide with lower dermal toxicity

3. Using the least toxic formulation and

4. Using the lowest feasible concentration.

Contamination

Since the hazard due to a pesticide depends on the extent and period of exposure of an operator, assessment of exposure has to be determined for the realization of hazard in the handling of a particular pesticide. This is essential because the hazard can be considerably reduced even in handling a toxic pesticide, if it is applied by an experienced operator, properly equipped and protected.

Protection to spraymen

The various items of protective clothing that may have to be used include hats, veils, overalls, aprons, rubber boots, gloves and face masks.

Personal hygiene

i. Spraymen should be provided with atleast two uniforms to allow for a change when required.

ii. Washing facilities with sufficient water and soap should be made available in the field at appropriate location.

iii. All working clothes must be removed at the end of each day's operation and a shower or bath taken.

iv. Working clothes must be washed regularly, frequency depending on the toxicity of the pesticide used.

v. Particular attention should be given to washing gloves, as contaminated gloves may be more dangerous than not wearing gloves at all.

vi. Spraymen should clean themselves before eating.

vii. Smoking, eating and drinking during spray operation must be strictly forbidden.

viii. When work involves insecticides of relatively high toxicity, the hours of work must be arranged so that exposure to the material being used is not excessive; transport should be arranged so that there is not a long delay between the end of the days's operations and the return to the base for washing.

Safety during preparation of spray material

The greatest degree of exposure occurs during handling of the concentrates and facilities for their safe handling must be provided. When compounds of relatively high mammalian toxicity are to be used by non-commercial operators, these compounds should be supplied in diluted form.

In preparing concentrates of water-dispersible powders, use must be made of deep mixing vessels and long-handled mixers to protect the operator from splashing and to permit stirring from a standing position.

Long-handled dippers or scoops should be used for transferring the insecticide from one vessel to another. The concentrates may be subdivided into bags or small containers

suitable for safe mixing by the spraymen in the field.

All small containers should be secured and packed to withstand transport to the periphery of the area of application.

Adequate protective clothing should be made available for those handling concentrates. Adequate washing facilities must be immediately accessible so that spills on the skin can be quickly removed.

The hazard of a pesticide in relation to the extent of exposure (contamination) can be reduced by:

1. Wearing appropriate protective clothing
2. Avoiding contact with insecticide to the minimum level and
3. Mastering the techniques of application.

The period of exposure (Time)

The exposure of spraymen to pesticides in confined areas, in residual spraying is among the highest in public health. Duration of work is one of the main factors influencing the extent of exposure. It is generally accepted that exposure should not exceed 5 hours a day and 5 - 6 days a week.

Therefore the hazard due to a pesticide in relation to the time of exposure can be reduced by:

1. Not exceeding prescribed working time for spraying
2. Washing contaminated skin during work and
3. Washing protective clothing frequently.

Hazard to public and safety precautions

During residual spray operations, the inhabitants should be told the purpose and the times of insecticide applications and should be given clear instructions as to what they have to do before and after the treatment of their houses like removing foodstuff and cooking utensils, staying out of the house during spray operation and entering the house after the floors have been swept or washed, etc. The collected sweepings should be either burnt or buried well beneath the earth away from the poultry and cattle.

During space spray operations, there must be prior consultation with the health authorities responsible for the residents. Special care must be taken to prevent the residents from re-entering the premises only after they have been adequately ventilated.

Disposal of empty or near-empty containers

The containers must not be allowed to go astray or be removed by unauthorized people, who might use them as containers for storing food or drinking water especially in areas, where such containers are scarce. Used containers can be effectively decontaminated by rinsing two or three times with water, scrubbing the sides thoroughly. If a drum has contained an OP compound, an additional rinse with soda (5 %) should be carried out. The solution should be allowed to remain in the container overnight. Rubber gauntlets should be worn during the work and a soakage pit should be provided for disposing the rinsings. The

emptied sachets and other toxic wastes should be burnt or buried.

Treatment of pesticide poisoning:

Successful treatment of pesticide poisoning depends on the rapid and simultaneous application of measures for (a) alleviation of life-threatening effects, (b)removal of non-absorbed material and (c) symptomatic and/or specific treatment.

The alleviation of life-threatening effects:

Use an oropharyngeal or nasopharyngeal airway or endotracehal intubation if airway obstruction persists. Artificial ventilation should be applied. Mouth-to-mouth respiration is to be avoided if the patient has been intoxicated by mouth because vomited material may contain dangerous amounts of toxic substances.

The removal of non-absorbed material: If clothing or exposed skin is contaminated by pesticide, the clothing must be removed and the skin washed with soap and water for atleast 10 minutes. Contamination of the eyes is treated by irrigation of the conjunctiva with water for 15 minutes.

Symptomatic and/or specific treatment:

Intoxication with OP compounds: Persons with or without signs of respiratory insufficiency should be treated with 2 - 4 mg of

atropine sulfate and 1 - 2 g of a soluble salt of pralidoxime or 250 mg of obidoxime chloride by slow intravenous injection. In cases of severe intoxication, 4 - 6 mg of atropine sulfate should be given initially to adults followed by repeated doses of 2 mg or as much as is required to maintain full atropinization. Continuous intensive observation of patients is essential since symptoms may recur and therefore observation should be maintained for at least 72 hours after initial improvement.

Intoxication with carbamates: In case of accidental poisoning or manifest symptoms, 1 - 2 mg of atropine sulfate may be given intramuscularly or even intravenously. Care should be taken to avoid overdosage in cases of carbamate poisoning especially in children. Oximes should not be given.

Intoxication with OC compounds: Artificial ventilation should be made. Anticonvulsant treatment with soluble barbiturates, diazepam or paraldehyde should be given in sufficient dosage to calm the patient and prevent convulsions.

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